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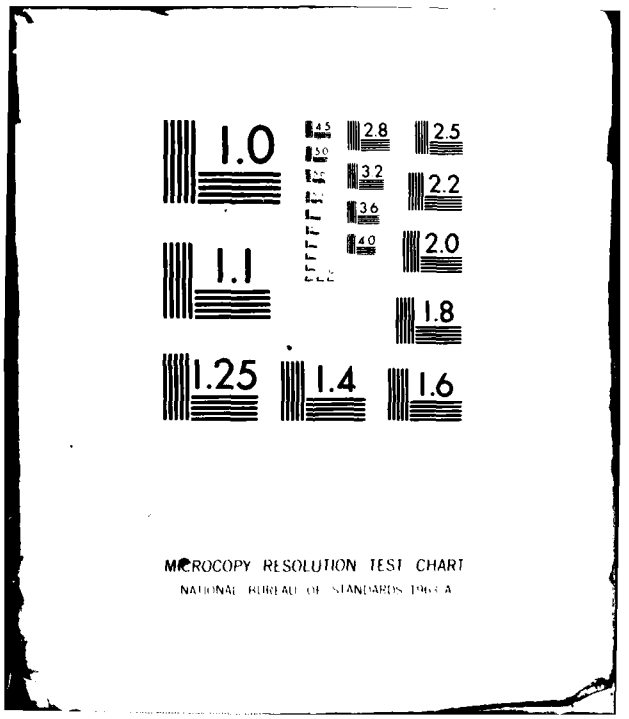
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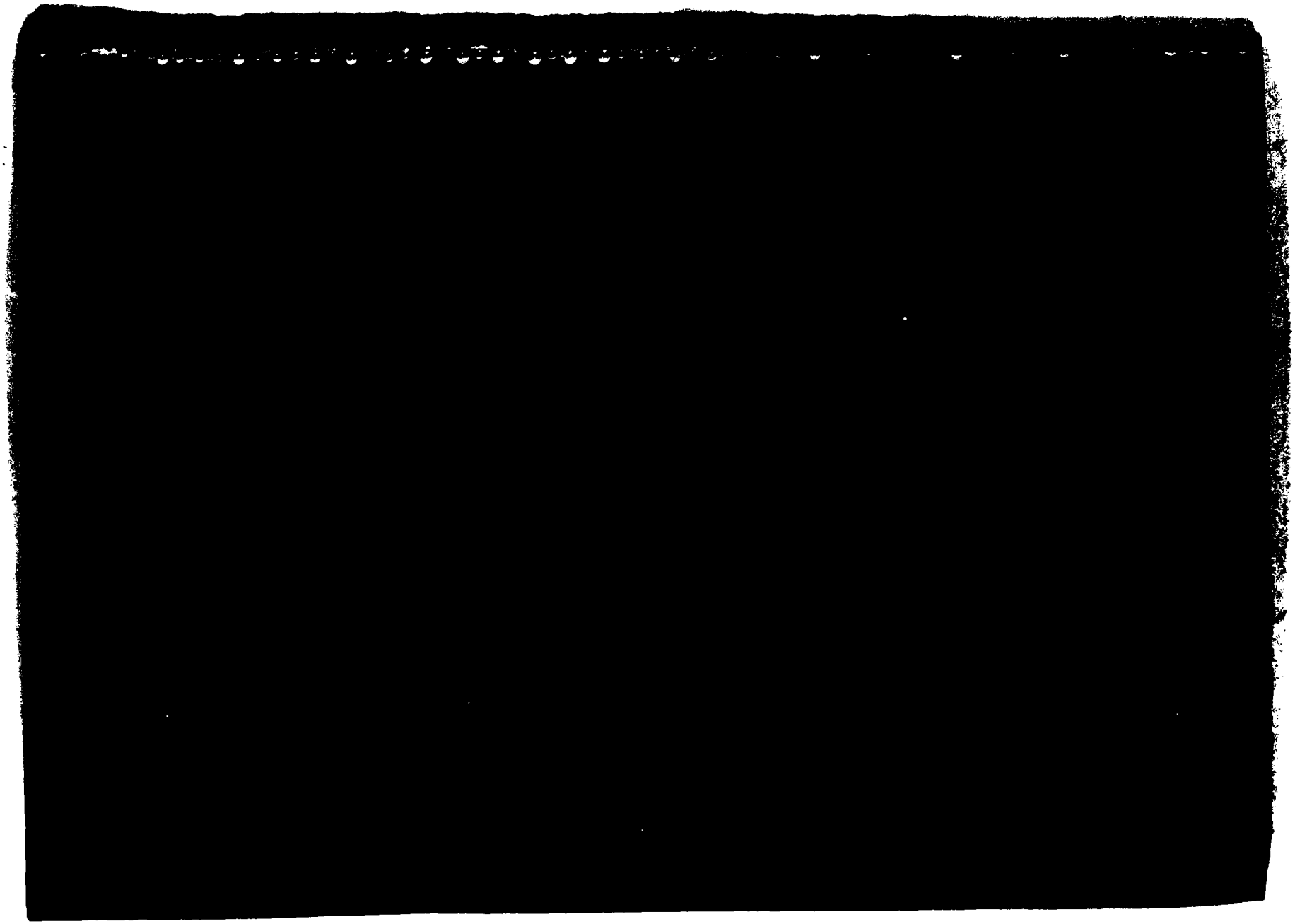

DEPARTMENT OF THE NAVY
OFFICE OF THE CHIEF OF NAVAL OPERATIONS
WASHINGTON, D.C. 20350

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From: Chief of Naval Operations
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Subj: 1979 Annual Report of the Center for Naval Analyses

Encl: (1) Subject Report

1. Every year a Board of Overseers reviews the work of the Center for Naval Analyses. This year's report (enclosure (1)) reviews CNA's research and use of Government resources from 1 October 1978 through 30 September 1979, and outlines the organization's program for FY 1980.

2. The report also includes a discussion of CNA's field program. This program is a distinctive feature of CNA which was established in 1942 as the Anti-Submarine Warfare Operations Research Group. The work of CNA's field representatives has continued to be of considerable value to the Navy and Marine Corps, both to the commands where these representatives are assigned and to the organization's general program of defense research. The description of this field program should be of interest to all who are concerned with the contribution of scientific research to the nation's defense.

3. The Navy and Marine Corps continue to be well served by CNA.

M. S. Holcomb
Vice Admiral, U.S. Navy
Director
Navy Program Planning

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45B	Marine Division
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FKA6A3A	Ship Research and Development Center
FKA6A3B	Coastal Systems Center

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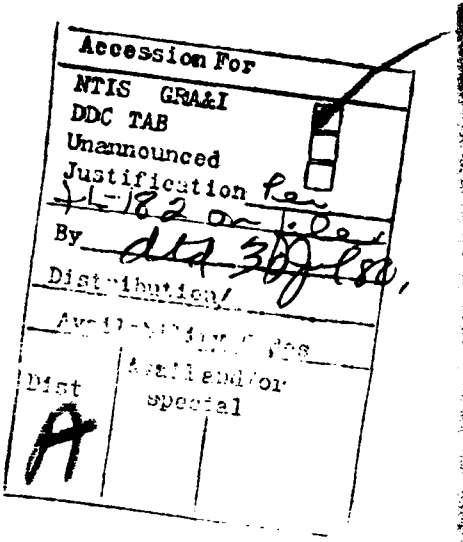

FOREWORD

Continuity and purposeful change were the themes of 1979 at the Center for Naval Analyses.

CNA field representatives symbolize the continuity of the organization. Since World War II, CNA and its predecessors have maintained operations research analysts at major commands of the Navy and Marine Corps. The field program, its contributions to the effectiveness of this nation's maritime strength, and its effect on the quality of CNA's research program, are singled out for special attention in the first section of this report.

The field program constitutes but one of CNA's close ties to its principal clients. We are proud that the closeness of these ties does not detract from the objectivity of our work. The credit for this balance of closeness and independence belongs equally to the CNA staff, the Navy and Marine Corps, and the University of Rochester.

The spirit of free inquiry that has been traditional in CNA work is guaranteed by the contract between the University of Rochester and the Department of the Navy. The quality of that inquiry is examined regularly by the Board of Overseers. We are pleased to note that Robert Sproull, President of the University of Rochester, joined the Board this year, further strengthening the bond between the University and CNA.

Another change was the Center's move to a facility designed to meet its special needs. The new building provides easy access to Navy and Marine Corps headquarters. It has as much usable space as the former quarters, and the long-run cost is slightly lower.

One organizational change was the merger of the Systems Evaluation Group into the Naval Warfare Analysis Group. This has strengthened CNA's ability to analyze the costs and effectiveness of future naval warfare systems. In recent years, the two groups had come to analyze similar types of issues. It was time to pool their skills and knowledge for the benefit of CNA's future research.

CNA's Executive Vice President, Andrew Borden, guided the organization for most of the year, while the President was on leave for professional development at the University of California at Los Angeles. Under Dr. Borden's direction, plans for improving the utility and timeliness of CNA studies were carried out.

The twelfth year of the Center's management by the University of Rochester was one of progress within a tradition of service. With pride, we submit this report of CNA's 1979 accomplishments.

David Kassing
President

W. Allen Wallis
Chairman of the Board

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I. CNA, AFIELD AND AFLOAT

At the end of 1979, CNA had 37 analysts at Navy and Marine Corps commands, from the western Pacific to the central Mediterranean, working closely with staff officers on immediate problems. These men and women serve in a tradition that began in World War II, with the Anti-Submarine Warfare Operations Research Group (ASWORG), CNA's forerunner. In war and peace, hundreds of CNA field representatives have made their full contribution to our nation's defense. They have also enriched the organization with invaluable knowledge.

In a tour of 1 or 2 years at a field command, a CNA analyst has enough time to understand the systems and operations he or she is to analyze. As employees of an independent organization, the field representatives need be concerned only with whether they report accurately on hardware developments, new operational concepts, or traditional combat doctrines.

But CNA field representatives have more to offer than an objective view of such matters. A field representative is often a veteran of several tours and of many related projects at CNA-Washington. Moreover, help from colleagues, with reinforcement from CNA's computer system and data repository, is no farther away than a letter, cable, or telephone call.

The data collected and analyses done in the field are important to CNA's formal study program. They form the basis for realistic estimates of how well present and future weapon systems may be expected to perform in combat. They suggest alternatives worth the attention of the Navy and Marine Corps. Returning field representatives are often able to follow up such questions at CNA-Washington. There they may work with teams of specialists in a specific warfare area or with interdisciplinary study teams examining a range of possible force structures.

The remainder of this section describes the field program more fully – where it has been, where it stands today, what it has accomplished.

HISTORICAL OUTLINE

In early 1942, the naval war against the Axis powers was going badly. In the Atlantic, merchant ships were being lost in great numbers to an ever-growing fleet of German U-boats. For help, the U.S. Navy turned

to operations research, a body of techniques that the British had found effective. By May 1942, the ASWORG was founded; within three months, its research was helping the Navy in the Battle of the Atlantic. At the end of the war, the successes of operations research led to establishment of the Operations Evaluation Group (OEG), now a component of CNA.

A main lesson drawn from the experience of World War II was that civilian scientists could work hand in hand with the military, that they could contribute significantly to military effectiveness. Although the relationship between scientist and officer is now common, it was a unique and important achievement at the time.

Another important lesson was that the central group must maintain direct, two-way communication with operating forces, afield and afloat. Only thus can the work be fully responsive to the needs of those operating forces. The arrangement worked out with the Navy called for individual scientists to work with deployed elements of the fleet and with other commands.

These lessons have been applied for four decades, in peace and war. Today, those field representatives who work with Navy commands are assigned to OEG; representatives at Marine Corps commands are members of CNA's Marine Corps Operations Analysis Group (MCOAG).

The figure on page 3 shows the numbers of representatives assigned to Navy and Marine Corps commands over the years. The number of such assignments dropped at the end of World War II; during the Korean conflict, the number rose to nearly the World War II peak.

The analyses and data that grew out of the Korean conflict, in addition to their immediate value to the Naval forces, laid the foundation for many later studies of air warfare and carrier operations.

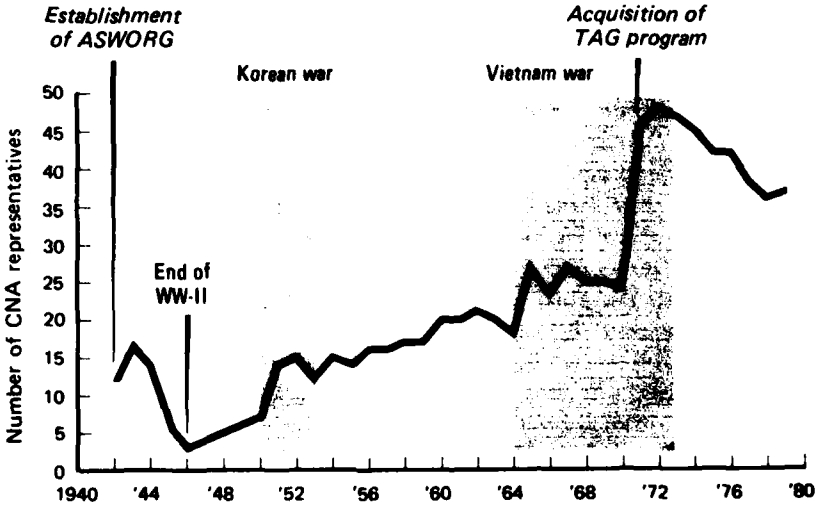
There was some growth through the peacetime era of the mid-1950s to mid-1960s, matching the gradual overall growth of the organization. With U.S. involvement in the Vietnam War, the Navy and Marine Corps asked for more operations analysis help, and CNA responded, even though the organization found it difficult to carry out so many assignments. CNA realized that the value of much of its long-range

research depends on experience with operational systems. In several instances, the new field billets that were established proved to be of such value that they have been kept up without interruption, ever since.

Growth of the field program was also stimulated by CNA's acquisition of the Tactical Analysis Group (TAG) effort, which became part of OEG in 1971. At first, the program focused on antisubmarine warfare, specifically tactical and operations analyses for Naval operating forces. Later, TAG became the analytical core of the Navy-wide Tactical Development and Evaluation program, and TAG research was broadened to include all types of naval warfare.

In recent years, following the end of the Vietnam War, the field program has been reduced slightly, but it remains much larger than it was in the mid-1960s. It would be possible to maintain a larger field program by reducing the frequency of rotation between the field and Washington, but rotation is essential if the research program at CNA-Washington is to benefit from the insights and knowledge that field experience gives to an analyst, and if the opportunities to gain this experience are to be made widely available within CNA.

FIELD ASSIGNMENTS: FOUR DECADES



FIELD OPERATIONS TODAY: WHERE, HOW, AND WHO

The map and table on pages 6 and 7 show where CNA's 37 field analysts serve.

At the Navy's force, fleet, and theater commands, the OEG analysts have a variety of tasks. They help develop war plans involving alternative force dispositions. They take part in planning and evaluating exercises to find out what present forces can do. Their analyses of the exercises often suggest new tactics to make the forces more effective. The forces analyzed may consist, on the one hand, of a single type of unit – say, an antisubmarine patrol aircraft, performing a specific task, such as maintaining a barrier against enemy submarines. On the other hand, the analysis may be concerned with large task forces, engaged in all phases of air, surface, and subsurface combat. Soviet naval tactics and capabilities, too, are analyzed when their operations and exercises bring them near U.S. Naval forces.

At the test and experimental facilities, OEG analysts help in the operational testing and evaluation of major antisubmarine warfare, antiair warfare, strike, and combat support systems. They develop test plans and data collection plans, observe the tests, analyze the data, and help to arrive at conclusions and recommendations.

The work of MCOAG analysts is analogous to OEG's. Field representatives with the Fleet Marine Forces help the Marine Corps evaluate current force capabilities. At the Marine Corps Development and Education Center, their research ranges from evaluating new operational doctrines and force structures to testing hardware prototypes.

In sum, field representative help to assess current readiness and effectiveness, and they look for ways to improve both. They work on the development of tactics. To try out the latest concepts and equipment, they help to design exercises and then evaluate the results. In addition, they help with the final testing of new equipment, both to make sure it is ready for use and to find the best ways to use it.

All this involves a wide variety of Navy and Marine Corps equipment, tactics, and operations – surface ships, submarines, aircraft, missiles, tanks, landing craft, communications, intelligence – and often the complex interrelationships among them.

For field research to be pertinent, the CNA representatives must work under the same conditions as the military staffs they are assisting. At several field billets, it is part of the job to spend weeks or months aboard ships of the fleet. Even on assignments at shore-based commands, it is common for analysts to spend considerable time aboard ships and aircraft or with troops in the field. Knowing the conditions under which Navy and Marine Corps forces operate is essential if recommended tactics or weapon system deployments are to be effective in combat.

For the most part, CNA's field representatives operate on the concept of one command, one analyst. The analyst generally has a great deal of autonomy and, as a civilian, is able to work closely with all echelons. This is necessary if the analyst is to understand the operations and systems he is studying. The arrangement strengthens the pertinence and objectivity of his analyses.

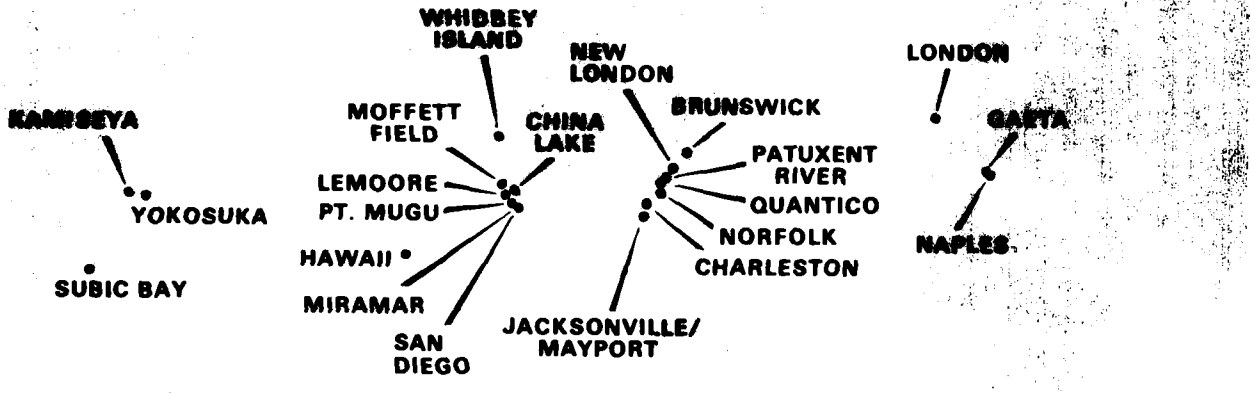
At some commands, the analyst's work fits into well defined analytic programs; at others, the analyst has a freer hand in selecting the program to study. Much depends on the interaction of the individual analyst with the commander and his staff. The final decision regarding the problems to be analyzed rests with the commander. The analyst is responsible for the analytic methods used; CNA is responsible for evaluating the quality of the analysis.

Though field representatives act with considerable freedom, they have close communication with – and direct support from – CNA-Washington. Shorter assignments are sometimes made, to provide the regular field representatives with additional analytical help for exercises or other special projects.

Frequently, the directors of OEG and MCOAG visit commands where CNA representatives are assigned. Meeting with the commanders and key members of their staffs, they evaluate projects that are being considered for analysis, and advise on the best use of the analysts. They also bring back to Washington a better understanding of analytical problems in the operating forces, an understanding that helps to shape the study program at CNA-Washington.

To ensure continuing cross-fertilization between the field and CNA-Washington and to provide for quality control of the field work, field

CNA IN THE FIELD



ASSIGNMENTS IN 1979

BRUNSWICK
Commander, Patrol Wings, Atlantic Fleet

CHARLESTON
Commander, Cruiser-Destroyer Group Two[1]
Commander, Mine Warfare Command[1]

CHINA LAKE
Air Test & Evaluation Squadron Five

GAETA
Commander, Sixth Fleet

HAWAII
Commander-in-Chief, Pacific Fleet
Commander, Third Fleet[2]
Commander, Submarine Force, Pacific Fleet[2]
Commanding General, Fleet Marine Force, Pacific

JACKSONVILLE/MAYPORT
Commander, Cruiser-Destroyer Group Twelve
Commander, Sea-Based ASW Wings, Atlantic Fleet

KAMISEYA
Commander, Patrol & Reconnaissance Force, Seventh Fleet

LEMOORE
Commander, Light Attack Wing, Pacific

LONDON
Commander-in-Chief, U.S. Naval Forces, Europe

MIRAMAR
Commander, Fighter Airborne Early Warning Wing, Pacific Fleet

MOFFETT FIELD
Commander, Patrol Wings, Pacific Fleet[3]

NAPLES
Commander, Attack Carrier Striking Force, Sixth Fleet
Commander, Submarine Force, Sixth Fleet
Commander, Maritime Surveillance & Reconnaissance Force, Sixth Fleet (Naples)[3]
Commander, Area Antisubmarine Warfare Force, Sixth Fleet

NEW LONDON
Commander, Submarine Development Squadron Twelve

NORFOLK
Commander-in-Chief, Atlantic/U.S. Atlantic Fleet
Commander, Naval Air Force, U.S. Atlantic Fleet
Commander, Second Fleet
Commander, Surface Warfare Development Group
Commander, Tactical Wings, Atlantic Fleet
Commander, Operational Test & Evaluation Force
Commanding General, Fleet Marine Force, Atlantic

PATUXENT RIVER
Air Test & Evaluation Squadron Five

PT. MUGU
Air Test & Evaluation Squadron Four

QUANTICO
Commanding General, Marine Corps Development & Education Center[2]

SAN DIEGO
Commander, Naval Surface Force, Pacific Fleet
Commander, ASW Wing, Pacific Fleet
Deputy Commander, Operational Test & Evaluation Force, Pacific

SUBIC BAY
Commander, Attack Carrier Striking Force, Seventh Fleet

WHIDBEY ISLAND
Commander, Medium Attack Tactical Electronic Warfare Wing, U.S. Pacific Fleet

YOKOSUKA
Commander, Seventh Fleet

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[1] *Joint assignment*
[2] *Two billets*
[3] *Vacant billet*

representatives regularly send back reports of their analyses. This correspondence is made available to those within CNA who need up-to-date fleet information in their studies. In turn, the field representatives are kept informed of CNA work related to the interests of their commands.

Once a year, CNA's analysts, from the field and Washington, convene with senior Naval officers in Washington, to discuss current problems and research in selected warfare areas. These meetings offer the CNA analysts a further opportunity to learn from their colleagues about analytic methods, data, models, and results that they may be able to use. At the same time, key decision-makers in the Navy learn about CNA research that can help them do their jobs better – and tell CNA of new problems that need analysis.

Manning the field program poses a considerable challenge. To assign qualified and versatile analysts, with the independence and resourcefulness to perform well under frequently rigorous conditions on a military staff, CNA trains and screens candidates for the field program with particular care. An "average" CNA field representative is on his second field tour, has spent more than 2 years in the field, and has been at CNA for more than 6 years. A number of field representatives have considerable experience at CNA and in the field: 21 of the 37 have been at CNA more than 5 years; 11 have had 3 or more field tours.

Because of the policy of rotating analysts between the field and Washington, half of CNA's professional staff has had field experience; there are as many analysts with field experience at CNA-Washington as there are on assignment. Eighteen of these are working on projects closely related to field activities. Nearly as many are engaged in studies of future force composition to which they bring the tempered sense of the possible that field experience gives.

SOME ACCOMPLISHMENTS

The history of the field program is interwoven with the history of CNA itself. Many of the results summarized here represent joint efforts between analysts in the field and analysts in Washington.

Of many contributions during World War II, these were among the more significant:

- More effective plans were devised for protecting convoys – specifically, where to place the screening warships in relation to the merchant ships being guarded.
- The preferred size of convoys was determined.
- The analysts also determined the effects of ship speed on convoy safety; the best depth at which to explode depth charges; the proper distribution of effort among escorts, submarine hunters, and patrols; the optimum patterns and altitudes for flying antisubmarine patrols; and the best use of airborne radar.
- Before the Germans' acoustic torpedo could come into wide use and become a real threat, its capabilities were analyzed, and countermeasures were developed.

The work underlying these accomplishments had these lasting effects on the methods of operations research in general:

- Search theory was developed.
- A technique was devised for estimating the effectiveness of formations of warships used to protect convoys from attacks by submarines.
- Some of the first operational models of radar and sonar performance were developed.

The World War II efforts and analytic methods are summarized in OEG Report 51, "A Summary of Antisubmarine Warfare Operations in World War II"; OEG Report 54, "Methods of Operations Research"; and OEG Report 56, "Search and Screening" – all still accepted as authoritative in many respects.

During the Korean War, analysts assigned to the western Pacific collected data from combat operations, solved tactical problems, and recommended improvements, many of which were effective in improving Naval combat operations. Important contributions were made in these areas:

- Selection of weapons for use by Naval aircraft against tactical targets. (The criteria were still in use by the fleet at the start of the Vietnam War.)
- Scheduling of close air support.
- Tactics for jet fighters.
- Naval gunfire against shore targets.
- Efficiency of blockade tactics.
- Interdiction of road and rail traffic.

Much of the information gathered and organized for these analyses (concerning, for example, aircraft losses, combat sorties, and naval gunfire missions) was used extensively for research and development and planning over the next decade. Moreover, today's models of aircraft carrier operations are built upon analyses done during the war.

After the Korean War, field representatives were often in the forefront of efforts to develop more effective plans and tactics for Naval forces. The work ranged from tactics for ship self-defense to plans for flying nuclear strikes from aircraft carriers.

An important concern of the Navy – then as now – was the problem of preventing enemy aircraft and submarines from quickly locating and attacking aircraft carriers. One field representative developed a method of dispersing a carrier task force to make less obvious the carrier's position among the many ships of the task force. He designed and analyzed a series of exercises to test the concept, which had the extra advantage of increasing the exposure of the attackers to the task force's defenses. The tactic was adopted.

In the late 1950s, a representative assigned to the U.S. Sixth Fleet was concerned with the adequacy of stocks of ammunition. His detailed analysis of the ordnance that would be consumed in the event of a large conventional war in Europe showed that standard Navy planning factors were far off the mark. Moreover, he identified critical imbalances between the types of ammunition the Navy would be most

likely to need and the types on hand or on order. His work was fully endorsed by the fleet commander and led to revised Navy planning for procurement of ammunition.

Research in antisubmarine warfare (ASW) was the mainstay of field operations in World War II. Though never neglected after that, ASW regained the spotlight in the 1960s, when CNA representatives helped to design, participated in, and analyzed a series of major fleet exercises involving ASW operations. Drawing on this work, CNA later published six studies that evaluated major components of the Navy's ASW forces and pointed out ways of correcting serious weaknesses.

From 1965 through 1972, analysts in the field and Washington made extensive studies of the Navy's operations in Southeast Asia. They evaluated the performance of new aircraft and weapon systems, and they assessed the effectiveness of the naval campaign.

A great deal of attention was paid to aircraft losses, particularly those exacted by ground defenses. Some of the analyses were translated into changes in tactics; losses were reduced as a result.

Other analyses in the *Vietnam War* included studies of river warfare and the effectiveness of naval gunfire, as well as the use of remotely monitored sensors. A major effort was devoted to the Market Time operation, the air and surface effort to keep supplies from reaching the enemy by sea. CNA analysts were involved in Market Time from the operation's inception until the end of the U.S. military role in Indochina. Their work focused on the nature and effectiveness of the barrier. They helped to design the Market Time patrols, gauged their effectiveness, and suggested changes in patrol configuration and force makeup as the nature of the infiltration threat changed. They were also involved in the work that led to the decision to install a coastal radar system.

Some of the other subjects of research carried out by CNA field analysts for the Navy during the Vietnam War were these:

- Recovery of downed aircrews
- Tracking of enemy aircraft

- Attacks by aircraft against transport of military supplies in North Vietnam
- Air-to-air combat.

And, for the Marine Corps, CNA's field analysts worked on:

- Patterns of enemy ground attacks
- Casualties caused by mines and booby traps
- Reconnaissance patrol operations
- Aircraft shelter requirements.

The Vietnam War also brought noncombat problems that needed analysis. In 1966, the Navy found that the fleet system of broadcast communications in the western Pacific was deteriorating, that delays of many hours – and even days – were becoming more common. Details of the problem and its likely causes were reported by CNA field representatives. A Washington-based analyst developed a model of the broadcast system and devised and executed a data-collection plan at a Navy communications station in the western Pacific. His analysis led to reductions of about 50 percent in the numbers of messages handled by ships, while reducing by 70 percent the numbers of messages missed by the intended recipients. These useful changes were applied throughout the Navy.

With the end of U.S. involvement in the Vietnam War, attention shifted to new challenges. For the Marine Corps, for instance, CNA field representatives have been planning and analyzing a major series of tests to help find the best aircraft for close air support of ground forces. Considerable effort has also gone into analysis of personnel issues: the quality and turnover of personnel, as well as problems of alcohol abuse and crime. With regard to quality and turnover of personnel, analyses in the field have contributed to later studies at CNA-Washington, designed to help the Marine Corps find ways to enlist recruits of higher quality and induce them to stay. Considerable attention has also been paid to the readiness of Marine combat units and the management of resources to raise that readiness.

An important subject of research for the Navy has been selection and use of strike aircraft.

The nation has made a large commitment to carrier-based aircraft and expects its carriers to control much of the sea in wartime. But aircraft and carriers have been growing larger, more complex, and more costly. As a result, the Navy has not been able to buy as many of them – thereby reducing the number of areas to which carriers can be deployed and increasing the risk associated with the loss of any one carrier. These trends have brought two issues into focus:

- Should the Navy have a small number of large aircraft carriers or a larger number of smaller carriers?

- Should the Navy stay with the types of aircraft that operate from today's carriers or buy aircraft that can land and take off vertically (V/STOL aircraft), instead?

In the fleet, CNA studied the operations of today's Harrier V/STOL aircraft, to see what opportunities and problems such aircraft may present in the future. A CNA analyst drafted the test plans for the first evaluation of the use of V/STOL aircraft from an aircraft carrier and, at the request of the Navy, supplied analytical support throughout the evaluation. Among other matters, the analyst examined the conditions under which V/STOL aircraft could operate, the ability of the V/STOLs to operate from the same carriers as conventional aircraft, whether V/STOL aircraft could operate from ships other than carriers, and how well a carrier might operate if its only aircraft were V/STOLs.

The analyst's report on these tests provided the Navy, Marine Corps, and aircraft industry with valuable insights into the design and use of V/STOL aircraft. The analyst also developed a model of V/STOL aircraft operations that was used in the CNA-Washington study of the costs and effectiveness of alternative forces of sea-based aircraft and the ships that carry them. The model was a further development of those used during the Korean War.

Soviet submarines armed with cruise missiles pose a formidable threat to these carrier forces, and the U.S. Navy, in defense, is relying heavily

on nuclear attack submarines. CNA analysts, in the field and in Washington, have continued to help formulate and test procedures for using our submarines in this role. The analysts have been instrumental in developing not only the techniques needed to evaluate their performance, but also the related command and control procedures. The results have helped to improve coordinated operations by surface and subsurface forces in defense of carrier task forces.

In the next decade, the Harpoon missile will become an important long-range weapon for the Navy. To realize its potential, the Navy must be able to detect, classify, and fire at targets at distances previously unheard of in surface warfare. Developing the operating doctrines and training methods requires considerable testing. CNA field analysts have been deeply involved in setting up and evaluating the Navy's test exercises. They have helped design exercise procedures, have recommended tactics, and have analyzed the exercise results. The analyses have pointed the way to changes in targeting criteria and operating doctrines that will improve Harpoon effectiveness. The analyses have also shown up deficiencies in surveillance, coordination, and training that the Navy can correct before Harpoon comes into wide use.

One important lesson of the Vietnam War was that training fighter crews intensively in simulated aerial combat improved significantly their chances against real fighters. Drawing on this experience, CNA analysts created a system for analyzing the complexities of aerial combat. The models they developed have generated realistic measures of combat effectiveness, measures that reflect more realistically the dynamics of such combat. The system enables the Navy and Marine Corps to assess present training procedures and improve them, to rate the readiness of pilots and aircrafts for combat, and to assess fighter tactics.

Of great importance to U.S. maritime power is knowing how the Soviets operate their naval forces and finding ways to exploit this knowledge. CNA field representatives have assumed responsibility for on-scene analysis of Soviet operations and exercises. Analyses of Soviet exercises have helped to identify a variety of tactics and have supported efforts to gauge the effectiveness of those tactics. They have useful implications regarding the Soviets' command and control

procedures, operational capabilities, and mission objectives. The result is a more complete picture of Soviet capabilities and, consequently, better planning by the U.S. Navy.

This is some of what CNA has accomplished – afield and afloat – in the interest of more effective naval forces. If war should come, the Navy and the nation would be better prepared as a result of these efforts – and CNA would be prepared to redouble its activity.

II. 1979 RESULTS

The selected examples in this section represent part of CNA's research during FY 1979. Some projects can not be described without divulging classified information. In a few instances, this report discusses projects from which classified details have been excluded. Nevertheless, we feel that these brief descriptions give something of the flavor of CNA research in the past year. The research outlined here is reported in detail in CNA publications. The classified publications are available to qualified recipients.

These are the subjects covered:

Future Naval Missions and Concepts of Operation
- *Sea War 85*
- Nuclear war at sea
- Rules of engagement
- Forward operations by submarines

Future Naval Forces
- Battle forces for the future
- Protecting the fleet from aircraft and missiles
- Helicopters for antisubmarine warfare
- Tomorrow's amphibious ships and landing craft

Navy *Logistics* and Manpower
- COD aircraft for the Navy
- Report cards for fighter aircrews
- Retaining pilots
- Race and recruiting

Current Naval Operations
- Antisubmarine warfare
- Air warfare
- Mine warfare
- Tests, exercises, and tactics

Research for the Marine Corps
- Laser designators
- Other examples

Other Research at CNA
- How finances influence airline safety and services
- Exploratory Research Division (ERD)
- Naval Abstracts

These examples are followed by titles of the unclassified research conducted at the University of Rochester under the CNA contract.

FUTURE NAVAL MISSIONS AND CONCEPTS OF OPERATION

Sea War 85

At the close of World War II, the U.S. fleet – more than 3,000 ships strong – was the master of the seas. No potential adversary could even challenge its dominance. That period is over. In the past 35 years, the fleet has dwindled to less than 500 ships. At the same time, the Soviet Union has built a large, capable, ocean-going navy. Soviet combatants now operate alongside U.S. ships in such areas as the Mediterranean, areas that were once totally under the control of the U.S. Navy.

This change has sparked serious debate about the Navy and its missions, and the adequacy of its resources and programs. Much of the public debate has centered on numbers – the numbers of ships in the U.S. and Soviet fleets, the sizes of these ships, and the numbers of missiles, aircraft, and guns they carry. These numbers are helpful, particularly in the perception of trends. But they do not tell the whole story. That would require a more detailed assessment of the objectives and capabilities of both fleets. CNA has undertaken such an assessment at the request of the U.S. Navy.

The aim of this effort is to estimate the ability of U.S. and Allied naval forces to carry out their missions in a non-nuclear war between NATO and the Warsaw Pact in 1985.

The study group has been investigating the possible objectives of both sides, the strategies they might use to pursue those objectives, and the likely outcome of the resulting naval campaign. All aspects of naval warfare – antisubmarine warfare, antiair warfare, surveillance, mining, and strikes ashore – are considered. The effects of geography and the contribution of the other U.S. services and the forces of our Allies, as well as the performance of individual weapon systems, are taken into account. Though the study is not complete, it has already produced a number of insights into the naval balance.

In some instances, new weapons and sensors appear to be compensating for the decline in U.S. force levels. Efforts in antisubmarine warfare, for example, are paying off. New sensors appear to be improving the Navy's capability to counter Soviet submarines, particularly along the sea lanes of the North Atlantic.

In other cases, however, the decline in the U.S. fleet is painfully evident. Though combat on land might be centered in Europe, the war would be worldwide for the Navy. The U.S. has vital interests in the Pacific and Indian oceans, as well as the Atlantic, and the Navy would find it hard to meet its objectives in all areas at once. Even in the Atlantic, some missions would probably have to wait.

Of course, the Soviet navy would not have an easy task. Quite the opposite, in fact. New weapons and sensors are improving the offensive and defensive capabilities of U.S. Navy ships and aircraft. And geography would work largely to the advantage of the U.S. and its Allies. Moreover, the Navy could count on assistance from a large number of Allied ships, capable of protecting both military convoys and merchant shipping. Their presence would enable the U.S. fleet to concentrate on destroying Soviet forces.

This study has already generated a great deal of interest in the Navy. The preliminary results and insights have been reported to a number of audiences in the Pentagon and in the fleets. When the entire study is completed, next year, it will provide information for addressing a variety of issues important to the Navy.

Nuclear War at Sea

In 1979, CNA's continuing assessment of Soviet military strategy and naval doctrine took up the question of how and why a conventional war with the Soviet Union might go nuclear. We looked, in particular, at the Soviets' incentives to start a nuclear war at sea.

Analysts, working with evidence derived from the Soviet force structure, doctrinal pronouncements, and naval exercises, have traditionally concluded that the Soviets will not wage nuclear war at sea until nuclear weapons are in fairly wide use on land. This belief is grounded in the dominance of the land campaign on the Central Front in Soviet planning decisions. The Soviets, it is said, will not risk the success of the land campaign at the conventional level by using nuclear weapons at sea.

In view of the evidence that Soviet attitudes toward nuclear war may differ from those of the West, the Navy asked CNA to analyze the likely outcome of a nuclear war at sea. The objectives of this effort

are to determine how Navy planning – for nuclear weapons, tactics, strategy, and force structure – might affect the Soviets' decision about starting a nuclear war at sea. The goal is to find ways to induce the Soviets not to use nuclear weapons.

The Navy has a variety of tactical nuclear weapons – simple gravity bombs, antisubmarine depth bombs, and warheads for antiaircraft missiles – for use if the nuclear threshold is crossed. Nuclear weapons alone, however, will not solve the problem. A variety of factors influence the survival of the fleet in a nuclear war: weapons, tactics, strategy, training, force structure, and ship design. Most important are the ways – and places – in which the fleet operates in the conventional phase of the war. If the fleet is employed wisely, much of it can survive the initial attack and go on to play a further role in the war.

This CNA study has resulted in several recommendations about specific Navy programs. But its greatest contribution has been to make the Navy more aware of the possibility of nuclear war. Results of the study have been reported to high-ranking Naval officers. The work has stimulated thought about steps the Navy should take to reduce the danger.

Rules of Engagement

CNA was asked by the Navy to assess the adequacy of present peacetime rules of engagement (ROE). ROE guide the behavior of military commanders during crises. The purpose is to authorize forms of action that enable the deployed forces to withstand attack without, however, increasing the likelihood that hostilities will break out. For the rules to be effective, everyone in the chain of command should understand the risks and benefits of any additional guidance put into effect during the crisis.

ROE are not a substitute for a strategy governing the use of forces. Rather, they are simply one tool for carrying out decisions made at higher levels of command. One example of the use of ROE to prevent escalation of isolated incidents is the guidance given to the U.S. Navy on how to escort ships or aircraft out of U.S. territory or airspace. Situations like these require specific rules designed to keep individual incidents from becoming threats to the peace.

Part of CNA's analysis consisted of a review of current rules, some of which date back to the early 1950s. We found that many of the rules are confusing, not suited to rapidly changing situations, and out of step with the problems that the fleet confronts now.

Our work resulted in a proposed set of rules that pertain to today's situations, lend themselves to fluid situations, and are codified for clearer understanding throughout the chain of command.

Forward Operations by Submarines

In World War II, U.S. submarines played a key role in the Pacific by operating behind enemy lines against Japanese naval and merchant shipping. From 1942 through 1945, U.S. submarines sank more than 5 million tons of Japanese merchant shipping and more than 200 Japanese warships. These exploits, though largely unknown to the public, contributed as much as the Battle of Midway to the ultimate U.S. victory.

At the end of the war the U.S. Navy dominated the seas; potential enemies did not have powerful fleets or critical sea lines of communication. The principal threat to U.S. maritime interests came from the large force of Soviet submarines. Two developments in the late 1950s – nuclear-powered submarines and submarine-launched ballistic missiles – heightened U.S. awareness of this threat. Soviet submarines operating in the broad reaches of the North Atlantic could disrupt vital sea lines of communication and launch nuclear strikes against the U.S. itself. Not surprisingly, the Navy placed great emphasis on antisubmarine warfare.

It soon became apparent that one of the most effective counters to the Soviet submarine was the U.S. submarine. A submarine could carry the new passive sonars to depths where they perform best. And once a target was detected, the submarine had the stealth to close for attack without alerting the prey. Consequently, for the past twenty years, antisubmarine warfare has been a prime mission of the U.S. attack submarine force.

Now, however, maritime affairs are again changing, imposing new demands on U.S. submarines. In the past ten years, the Soviets have constructed an impressive fleet of surface warships that complement

their submarine force. The combined might of the Soviet navy poses a threat to U.S. control of the seas, particularly near the Soviet Union. Once again, there may be a need for U.S. submarines to operate in areas under enemy control.

Several recent CNA studies have pointed out the need for submarine operations in waters where the Soviet navy may, at first, hold control. U.S. submarines can operate covertly in these areas from the very start of a conflict, disrupting enemy operations and paving the way for later operations by the U.S. fleet. But our analysis has also confirmed the belief that U.S. submarines would face a more difficult task. The opposition would consist, not of submarines operating independently but, rather, of submarines, aircraft, and surface ships operating in coordination.

It is imperative that U.S. submarine losses be kept to a minimum. The Navy has asked CNA to analyze possible improvements in future submarine systems. The study is not yet complete, but it is already apparent that there are relatively inexpensive actions the Navy can take to strengthen the ability of U.S. submarines to operate against the Soviet fleet. The study has also drawn attention to the potential importance of submarine operations in areas under enemy control.

FUTURE NAVAL FORCES

Battle Forces for Tomorrow

The Navy's ability to control the seas in wartime will depend largely on its battle forces – the aircraft carriers and the warships that both defend them and augment the striking power of their aircraft. Though the Navy's battle forces have become more effective, the threats to them have grown apace. Because it takes a long time to develop new aircraft, ships, and weapons, the Navy must make decisions in the next few years that will determine the fighting potential of its forces in the 1990s and beyond. These decisions cannot wait until new threats become well defined.

With the recent authorization of a fifth nuclear carrier, the most pressing question that now affects the composition of battle forces arises from the need to replace the Navy's aging fleet of cruisers and

guided missile destroyers. CNA is conducting a study to help the Navy decide what features the new ships should have and how many of these ships it needs.

The Navy must also choose a new generation of aircraft. Vertical/short takeoff and landing (V/STOL) aircraft can operate from ships that are much smaller than the present aircraft carrier. The Navy could then disperse its airpower more widely. But V/STOL aircraft cost more than conventional takeoff and landing (CTOL) aircraft of comparable performance. On the other hand, V/STOL aircraft take less time to launch and recover, they can operate from smaller ships, and, if the need arose, they could operate more easily from damaged ships. The issue is this: Do these attributes outweigh their higher cost? For the past two years, CNA has been studying the evidence. Though not all the results are in, it is already clear that V/STOL aircraft will not be a panacea.

The future of the Navy's battle forces does not necessarily rest entirely with new ships and carrier-based aircraft. CNA has been analyzing the possibilities offered by precision-guided cruise missiles, too. Such missiles could be placed on many warships, spreading the power of the fleet over a wider area and, at the same time, making it harder for an enemy to counter that power. Our analyses have suggested that cruise missiles would be a worthwhile investment, even though they are much more expensive than conventional ordnance. We are now looking carefully at the kinds of cruise missiles that are candidates for the fleet of the late 1980s.

Greater reliance on land-based aircraft would represent another departure from the conventional battle force. The Navy has, for years, been flying land-based patrol aircraft on antisubmarine warfare missions. The new Harpoon antiship missile now makes it possible for patrol aircraft to attack surface targets. If they carried improved radars and long-range missiles, they might also prove valuable in defense of the fleet against air attack. Land-based aircraft bring potential advantages to such roles: They can be designed and bought at a lower cost – pound for pound – than sea-based aircraft, and they can be built to operate at greater distances, with heavier payloads. But such advantages cannot be realized without suitable land bases. Some bases would have to be overseas, where their survival in wartime is uncertain. CNA analysts are now weighing the advantages and disadvantages.

In sum, the Navy faces many difficult choices in planning for the battle forces of the future. Though the final decisions may well hinge on political, economic, and military factors that cannot now be fully quantified, CNA has been working closely with the Navy to identify the available choices and shed light on them.

Protecting the Fleet From Aircraft and Missiles

For defense against air attack, a battle group needs a diverse and complex mix of ships, aircraft, and gun and missile systems. Over the past 25 years, therefore, the need to deal with more advanced aircraft and missiles, which the fleet is likely to encounter, has driven air defense to rely more and more on automation.

In modern air defense, airborne early warning aircraft detect enemy missile-launching aircraft and direct long-range fighters to intercept them before they can fire their missiles. The enemy aircraft and missiles that survive this attack then face long-range surface-to-air missiles (SAMs) launched from ships. The attacking aircraft and missiles that manage to penetrate this second defensive layer finally come up against a defense made up of short-range SAMs, guided gun projectiles, extremely-rapid-fire ballistic gunfire, decoys, and electronic countermeasures.

The fleet, accordingly, is acquiring a wide assortment of airborne early warning aircraft, long-range fighters, automatic detection and tracking radars, advanced air-to-air missiles, longer-range SAMs, sophisticated decoys, and the rapid-fire close-in weapon system. To forge these widely varying systems into an effective air defense, the Navy is using computers, data links, and voice communications. Integrating so many new systems into the fleet is sure to be hard. CNA analysts are helping the Navy to make the adjustment.

CNA analysts are evaluating tactics that will enable fighter aircraft and early warning aircraft to operate farther from their carriers despite the greater vulnerability of longer communications links to enemy electronic warfare tactics.

Other analysts, aboard ship, are evaluating procedures for operating automatic detection and tracking radars and for combining these radars with ways of identifying targets as hostile or friendly. The long-term goal is to improve the antiair tactics of the Navy's battle groups.

Helicopters for Antisubmarine Warfare

In recent years, passive sonar systems, with sensitive hydrophones and sophisticated signal processors, have improved to the point where, under the right conditions, they can detect submarines many miles away.

To take advantage of such detections, ships need a vehicle that can speed to the contact area, pinpoint the submarine, and attack it. To meet this need, the Navy has adopted the Light Airborne Multipurpose System, or LAMPS, which centers on a manned helicopter equipped with sensing devices and torpedoes.

Because the enemy submarines carry highly lethal weapons, sometimes including both antiship missiles and torpedoes, it is advisable to engage them as far from the protected forces as possible. The LAMPS helicopter, which operates at a distance, with little or no help from its parent ship, must be fairly large and – not surprisingly – expensive. Accordingly, though the antisubmarine strengths of LAMPS are sorely needed, the Navy can not buy as many as it wants. CNA was asked to devise an analytic basis for determining the number to buy.

This problem was particularly challenging because the solution depends heavily on factors that cannot be known in advance. Examples include Soviet submarine tactics, Allied shipping policies, and the precise deployment of the U.S. fleet in wartime.

The CNA analysts isolated the strategic, tactical, and technical factors that affect significantly the amount of protection afforded by LAMPS. Rather than make specific assumptions about these uncertain factors, they considered a range of reasonable values or alternatives for each, and showed how these variations affect the number of LAMPS helicopters the Navy should buy. The Navy's decisionmakers are enabled to choose a LAMPS inventory objective on the basis of their own judgment about the key inputs to the analysis. The Navy has found this approach useful.

Tomorrow's Amphibious Ships and Landing Craft

The amphibious forces of the Navy and Marine Corps can inject measured amounts of power into conflicts at the right places and right

times. Successful amphibious operations depend largely on having a mix of ships and landing craft that will get the Marines ashore quickly, ready to fight. Recent developments in landing craft technology, coupled with the need to replace many aging amphibious ships, have led to new analyses of the programs for amphibious forces.

In one study, CNA looked at alternative mixes of landing craft and ships. The landing craft considered were of three types: those now in use, an air-cushion craft, and an advanced planing-hull design. The amphibious ships analyzed include improved versions of present ships and two new-design lift ships. One of the new ships could carry air-cushion craft only; the other, a multi-purpose ship termed the LXA, could carry air-cushion craft and other vehicles at the same time.

We found that, for many mixes of landing craft, an LXA is the only kind of amphibious ship needed, and that, in all cases, it is an important component of the force. Further, we learned that a ship force dominated by the LXA would cost the least to buy and operate – about a fourth less than any other mix – whether the landing craft force consisted entirely of conventional craft or of new-design craft. The LXA is desirable, regardless of developments in landing craft. CNA recommended that the Navy develop the LXA concept in detail.

Another study shed light on the choice between air-cushion craft and today's types of landing craft.

The landing craft now used to carry Marines and their combat equipment to shore during an amphibious assault have not changed much from the ones designed and built during World War II. These landing craft have significant disadvantages. Because of their low speed – less than 10 knots – they must be launched close to shore to permit assault waves a reasonable turnaround time. As a result, the amphibious task force is vulnerable to enemy artillery and missiles.

In addition, today's craft must unload cargo on the beach, tending to create a logistics bottleneck and increasing the exposure of Marines and their equipment to enemy fire. Beach gradients, surf conditions, and such obstacles as sand bars and reefs limit the number of beaches suitable for landings by such craft. These constraints allow the enemy to concentrate his defenses on the relatively few beaches where landings are possible. Tidal conditions also restrict the time of operations. To minimize the time of special vulnerability in the surf and on

the soft beach, landings normally begin at high tide, allowing assault waves as much time as possible to get ashore before the tide recedes.

To overcome the disadvantages associated with today's craft, the Navy started work on two experimental air-cushion landing craft in 1971. Craft of this type, which ride on a bubble of compressed air without touching the water, are similar in operation to the hovercraft now serving as ferries across the English Channel. Because air-cushion craft travel at 50-60 knots, the amphibious task forces can stand off farther from shore and be less vulnerable to fire. Air-cushion craft can also unload their cargoes inland, avoiding the logistics bottleneck. Moreover, they can operate in sea states, surf or beach conditions that today's landing craft would find impassable. In short, these craft open more beaches to attack, more of the time. As might be expected, the new landing craft cost more, about four times as much to buy and operate as those they would replace.

Our analysis showed that the advantages of the air-cushion craft – its higher speed and its greater ability to land at a variety of sites, under a variety of conditions – will more than compensate for its higher cost, if the Navy replaces its older amphibious ships.

NAVY LOGISTICS AND MANPOWER

COD Aircraft for the Navy

The battle group – consisting of an aircraft carrier and the ships that accompany it – is responsible for a variety of missions. Readiness to carry out these missions means keeping large numbers of complex weapon systems, including almost 100 aircraft, fully operable. A variety of skills and large numbers of spare parts are needed.

But a carrier simply lacks the space for all spare parts and for all the specialists who use them. Critically needed personnel and parts are therefore flown from wherever they are in the world to the base or airfield closest to the carrier. Carrier-onboard-delivery (COD) aircraft then fly them to the carrier.

Today's COD aircraft are old, and the Navy has been trying to buy new ones since 1972. But Congress has turned down these requests, in

part because of uncertainty about what these aircraft would be expected to carry. The Navy asked CNA to look at the COD problem, with special emphasis on determining what the COD aircraft should carry. Although the problem had been studied before, the Navy wanted a new, unbiased look at the issue.

CNA began by laying out the situations in which battle groups are likely to be involved, selecting for consideration the aircraft that could be used in the COD mission, and estimating the demand for personnel and parts. The scenarios consisted of peacetime operations, four crises, and a war between NATO and the Warsaw Pact. The aircraft considered were derivatives of present designs; new-design aircraft would cost too much for research, development, and testing.

The study group and the Navy agreed that the COD aircraft would carry high-priority personnel and cargoes only. A demand for a spare part was considered high in priority if an aircraft or a ship's system could not perform its mission without it. Mail was included; many spare parts come by mail. A demand for a person was considered high in priority if the person was a technician who had to help make critically needed repairs. Demand for additional personnel during crisis and war was also considered.

CNA's analysis showed that the Improved C-2 aircraft, derived from the E-2C, was the least expensive aircraft that could carry out the COD mission. The study group found that each battle group would need about 1,300 cubic feet and 15,000 pounds of COD deliveries a day in wartime. CNA analysts then worked with the Navy to find out how many Improved C-2s should be bought and how these new aircraft would fit in with the few COD aircraft now in the inventory. The Navy is taking steps to carry out CNA's recommendations.

Report Cards for Fighter Aircrews

In late 1971, CNA began developing methods for evaluating the ability of fighter aircraft to maneuver during combat with other aircraft. The question behind the effort was whether the AV-8A Harrier – an aircraft capable of vertical take-off and landing – has any special ability to survive an attack by enemy fighters.

The first method emphasized measurement of the ability of the aircraft to maneuver. When this method had been used successfully in several test engagements, a method was devised to quantify the effects of maneuvering while firing weapons. By mid-1975, several methods – including other maneuvering models – were available, and their usefulness had been demonstrated with data gathered on test ranges.

These methods for evaluating air combat, though born and matured in the test and evaluation community, were clearly applicable to the training and evaluation of fighter aircrews. At the time, however, their applicability to aircrew performance was limited by the lack of readily available data from routine fleet engagements. Until then, the data collected on test ranges was reduced by hand, an arduous task. But the use made of the Navy's Air Combat Maneuvering Range (ACMR) in the mid-1970s made it possible to collect and reduce the data automatically. The way was now open for regular use of these analytic models.

In 1975, CNA designed a software system that would automatically reduce and analyze data collected on the ACMR. The system – known as the ACMR Readiness Estimation System (ACMR RES) – became operational in 1977. Control of the ACMR RES was turned over to the Fleet Analysis Center. To date, the system has been used to evaluate the performance of squadrons (rather than of individual aircrews) in air-to-air combat.

Since development of the basic system, CNA has been adding other features to the software. In 1979, for example, CNA expanded the scope of the firing sequence model to yield estimates of the probability of shooting down the first enemy aircraft and of losing the first friendly aircraft, as the engagement goes on. This led to a procedure that enabled analysts to estimate the ratio of losses by both sides during engagements involving many aircraft. In its present form, the ACMR RES provides squadron and wing commanders with a method for quickly and conveniently evaluating aircrew or squadron performance – maneuvering, weapon employment, and tactics – in complex air-to-air combat scenarios.

The ACMR RES was first applied at the ACMR site in Yuma, Arizona; it has since been transferred to the East Coast ACMR at Oceana for

evaluation by aircrews. In addition, CNA maintains a master reference system that allows analysts to test proposed changes before they are incorporated into the ACMR RES.

Retaining Pilots

It costs the Navy $450,000 and 2 years to train a pilot. To recoup its costs, the Navy now requires every officer to serve 5 years after he becomes a pilot. The Navy also monitors closely the rate of retention after the term of obligated service.

But attrition among pilots who have completed their first obligated terms has been getting worse. In FY 1977, for instance, 15 percent of the lieutenant pilots who had completed their obligation left the Navy; in FY 1978, the figure was 24 percent. The rate of attrition during the first few months of this year suggests that the figure for FY 1979 will be as high as 29 percent.

Last summer, the Air Force, which had also been experiencing low retention among its pilots, was asked by the Office of the Secretary of Defense to develop a pay package that would reduce attrition. The Air Force recommended raising Aviation Career Incentive Pay (ACIP) – formerly known as "flight pay" – by 50 percent. ACIP, which varies between $100 and $245 a month, depending on years of service, is awarded to virtually all pilots and navigators, and to medical officers who have flying duties.

The Navy was asked to comment on the proposal. The Navy, in turn, asked CNA to determine the responsiveness of pilot retention to pay.

We set out to answer three questions. First, the Navy's question: What would be the response to a change in pay? That is, by how much would pilot retention increase, if pay rose a given amount? Second, what would be the costs of alternative increases in pay? We wanted to estimate the costs of increases in Aviation Career Incentive Pay and of bonuses awarded for various periods of service. Third, what would be the optimal change in pay; by how much should pay be increased?

CNA looked into historical data and found that pilots do, in fact, respond to changes in pay. We estimated the elasticity, that is, the

percentage increase in retention that results from a one percent increase in military pay. The median elasticity was 0.9, and the response was generally greatest among pilots who had just completed their initial obligation.

The analysts then computed the effects and costs of alternative bonuses and increases in ACIP. For example, a $5,000 bonus for 6 years has a greater effect on retention than a 100 percent increase in ACIP. Moreover, the bonus costs less than half as much as the ACIP increase. The fact is that a bonus is always the cheaper way to increase retention.

The reason is fairly straightforward. Approximately 30 percent of ACIP is paid to navigators and to medical officers in jobs that require flying duty. This money has, of course, no effect on pilot retention. Another 30 percent is paid to pilots who have not reached the end of their initial obligation. Only 40 percent of ACIP, therefore, is directed at increasing pilot retention. CNA, accordingly, recommended that the response to low pilot retention be a bonus targeted at officers who can leave.

To answer *the third question -- What would be the best bonus to pay?* -- we had to consider the Navy's need for pilots. The analysts used the Navy's current demand for pilots, though we realized, of course, that this may change. The analysts found that the optimal annual bonus is equal to 3 months' base pay and costs a total of 12 million in 1978 dollars when paid for 5 years after completion of the initial obligation. They also found that the training rate needed to meet the Navy's requirements is 1,000 pilots a year, far above the present figure. Accordingly, the Navy must raise not only the pilots' pay, but also the number of pilots it trains each year.

The Navy drew on the estimates developed in this study to calculate the effects and costs of alternative increases in pay. The Navy has also used these estimates to support its request for a bonus, though the pay package also includes the increase in ACIP.

Race and Recruiting

When the draft ended, the Navy set enlistment standards that required the enlistment of equal proportions of minority and majority recruits

with qualifications for Navy schooling and with high school diplomas. Early this year, the Navy was charged with bias because of this practice and turned to CNA for help in reevaluating the recruiting policy. CNA was in a good position to help because of its earlier work on closely related issues.

Alternative recruiting policies were devised on the basis of eligibility for Navy schooling, without any racial or high school graduation requirements. Expected numbers of enlistees, school-eligibles, and high school graduates were projected for each policy. Then, using parameters derived from a CNA longitudinal study of recruits through the first term of service, the analysts estimated recruit survival rates and man-years of service for each policy.

The alternative policies were shown to produce more recruits, more first-term survivors, more reenlistees, more man-years, and more high school graduates than the present policy. The Chief of Naval Operations selected the policy that set a single recruiting goal of 74 percent school-eligibles. At the same time, Navy programs were expanded to increase training and occupational opportunities for new recruits. Consequently, more men will qualify for enlistment, be trained, and be retained in the Navy.

CURRENT NAVAL OPERATIONS

Antisubmarine Warfare

CNA studied the problems that arise when two or more ships use their passive sonars to locate and attack a submarine. Each ship reports the direction of the submarine to an antisubmarine warfare coordinator (ASWC), who then assigns aircraft to attack. But the ships are often too far apart for line-of-sight communication, and other methods of communication may be too cumbersome and slow. CNA analysts therefore helped design an exercise to measure reporting delays for widely separated ships. They found that many reports never reach the ASWC and that delays are longest when timeliness is most important – when two or more ships have made valid detections. The analysts identified the better of two communications methods tested in the exercise and suggested methods that are even more promising.

Antisubmarine warfare (ASW) aircraft use torpedoes against enemy submarines. With data from exercises involving land-based ASW patrol aircraft, a CNA analyst calculated how accurately the torpedoes were dropped and what the probability was of hitting the target. By identifying the cause of each inaccurate placement or unsuccessful attack, his work went beyond previous analyses of the problem. The results showed how much weight should be given to improving each of the factors considered – systems, tactics, and training – to make the aircraft more effective.

After a land-based ASW patrol aircraft has flown a mission, the crew prepares a written report, describing the mission: When, where, and why was the mission conducted? What were the weather and ocean conditions? And what methods were used to find a submarine? The answers are stored in computers at major Navy commands. In August 1978, CNA started a project to provide analysts with computer-automated access to the information in these messages. Computer software, used to gain access to the message data, was developed through the joint efforts of CNA analysts and programmers and an outside organization. Overall mission performance, the performance of specified types of aircraft, and the use of sensors and software in the fleet were evaluated. The success of the project has led CNA to help other air antisubmarine commands to automate their access to information about their missions.

Air Warfare

Carrier aircraft are often called upon to search for ships near the battle group. The airwing commander must therefore be aware of the ability of every type of aircraft in his airwing for such a surface search. During a recent deployment of the USS Saratoga, a CNA analyst helped both the squadron and the airwing to evaluate this use of radar by the A-7E aircraft. Analysis of data collected during a test he designed showed how the A-7E could use its radar most effectively and provided measures of that effectiveness.

West Coast fighter/airborne early warning (AEW) commands have been working on an investigation of tactics used by fighter/AEW aircraft against enemy air raids. In the project, in which CNA has been taking active part, an evaluation is being made of coordinated fighter/AEW tactics when communication links are either not working well or not

working at all. The problem is complicated by the maneuverability of the targets and the requirement to station aircraft at considerable distances from the main force. Early findings suggest that fighters with even minimal communications can, in fact, engage raids successfully.

CNA has analyzed data from several exercise engagements between A-7E attack aircraft armed with a new model of the Sidewinder air-to-air missile and aircraft that simulated Soviet fighters armed with Soviet missiles. The goal was to find out how much better the aircraft could protect itself with this improved missile. Detailed analysis of the engagements revealed that the new missile is much easier to use than were earlier models. The analysts also concluded that the pilots of the A-7E attack aircraft should receive more training as fighter pilots to help them see enemy aircraft.

Mine Warfare

CNA analysts, continuing their work in mine warfare, have helped evaluate the reliability of the Captor and Mk 57 mines and have taken part in the Navy's effort to automate the planning of minefields and to develop ways to measure their effectiveness. One analyst, for example, has helped develop a way to calculate the number of mines needed in a given situation and is developing computer programs that will enable carrier staffs to plan minefields.

Tests, Exercises, and Tactics

Every year, the Navy conducts many exercises. They enable commanders to estimate the effectiveness of their forces and to improve the employment of those forces. But the exercises must be reconstructed, that is, analyzed for an accurate picture of what happened. CNA analysts with the Seventh Fleet have been instrumental in speeding the reconstruction of major fleet-wide exercises. The results of an exercise thus become available while the memory is still fresh in the minds of those who took part. Moreover, what was learned can be made available sooner for the next exercise.

Testing aircraft tactics at sea takes so much time and money that many proposed tactics are never evaluated. To alleviate the problem with respect to the S-3 antisubmarine warfare aircraft, CNA analysts

worked on a project to evaluate new tactics in the S-3A Weapon System Trainer before testing them at sea. This preliminary evaluation sifts the tactics; those which show promise can be evaluated further.

As the Navy buys more Los Angeles-class nuclear-powered submarines, CNA has been helping to evaluate their capabilities and develop tactics for using them. Analysis has shown that this submarine has significant tactical advantages over earlier classes of submarines, because of its speed and sonar system. To support this program, CNA analysts have developed computer programs to evaluate the accuracy of simulated torpedo attacks. They have also developed a series of programs for use with small, hand-held programmable calculators, to help the submarine crews plan missions and analyze the movement of targets. All the submarines in the Atlantic Fleet have been provided with these programs.

Through several wars, radar has served as the "eyes" of the fleet. It has provided ships with critical targeting information for firing guns and surface-to-air missiles (SAMs). CNA is now helping the Navy to evaluate the effectiveness of the "ears" of the fleet – passive acoustic and electromagnetic sensors – in listening for the enemy. These systems can help the Navy locate enemy ships at long ranges, target surface-to-surface missiles beyond the horizon, and assess battle damage at long distances.

RESEARCH FOR THE MARINE CORPS

Laser Designators

It used to take hundreds of artillery shells or bombs to destroy a tank or other small, well protected target. But a new family of weapons, called precision-guided munitions (PGMs), has been developed. These weapons are so accurate that a single shot is often enough.

A forward observer on the ground "designates" the target by training an invisible laser beam on it. Sensors in the projectile then pick up the reflection and guide the projectile to it.

For this purpose, the Army has developed two designators: a light, short-range one and a heavier one of longer range. The small unit looks

like a short-barreled rifle, weighs about 17 pounds, and can be slung over the shoulder. The long-range unit weighs 58 pounds and is mounted on a tripod.

The Marine Corps has been developing a designator of intermediate range, the Modular Universal Laser Equipment (MULE). The 42-pound MULE, though basically a tripod-mounted designator, can also be operated while hand-held.

The designators range in total life-cycle cost from $20 million for the short-range unit to $65 million for either the long-range unit or the MULE. The Department of Defense directed the Army and Marine Corps to analyze the three systems, with respect to both effectiveness and cost. CNA did the analysis for the Marine Corps.

The analysts examined the three systems to find out which could, at lowest total cost, reach a given level of effectiveness against an array of targets. They considered the life-cycle cost, as well as the cost of replacing combat losses and buying ammunition.

The Marine Corps had another – and critical – concern: the man-portability of the three systems. To carry the long-range system, the forward-observer team would have to have an additional man.

The analysis showed that the Army's decision about the MULE is important. If the Army buys the MULE, it is the most cost-effective of the three systems. But if only the Marine Corps buys the MULE, the system is slightly less cost-effective than a variant of the long-range system. The long-range unit, however, has serious disadvantages for the Marine Corps: the need for an extra man to make it man-portable, and its bulk, which prevents its use where a smaller, hand-held device is needed. Consequently, CNA recommended that the Marine Corps continue to develop the MULE and buy it.

Other Examples

To control interceptors and surface-to-air missiles in the confusion of an enemy air attack, the Marine Corps has been developing an automated air control system, known as TAOC-85. The purpose is to replace a semi-automatic system that has been operating since 1966. The Marine Corps asked CNA to analyze the cost-effectiveness of

TAOC-85 and several alternatives. CNA found that TAOC-85 would provide a more effective air defense than the alternatives, that it offers advantages in mobility, operational flexibility, and availability. The system is also estimated to cost less than the alternatives and to require fewer people for operation and maintenance. Accordingly, CNA recommended buying a full-scale engineering development model for testing. The Marines are making the purchase.

Pay accounts and personnel records of the Marine Corps are managed with the aid of a semi-automated system known as the Joint Uniform Military Pay System/Manpower Management System (JUMPS/MMS), an integration of two separate systems. The effectiveness of JUMPS/MMS was first analyzed by CNA in 1975, when the integrated system came into existence. It has since undergone many changes, and the Marine Corps recently asked CNA to reevaluate the system to measure progress in reducing delays and losses of data. We found that most delays have been reduced significantly. Information losses have been almost eliminated.

The Marine Corps has been considering development of a lightly armored vehicle, the Mobile Protected Weapon System (MPWS). The vehicle would be light enough for lift by the CH-53E helicopter, to provide antitank and other direct fire support to Marine units that have landed by helicopter. As an alternative to developing its own vehicle, the Marine Corps asked CNA to evaluate existing foreign vehicles, or hybrids based on foreign and domestic components. After preliminary analysis, CNA recommended that the Marines obtain several Canadian Cougars for operational field tests. The Marines will run the tests in a few months.

OTHER RESEARCH AT CNA

The Possible Influence of Finances on Airline Safety and Services

In October 1978, President Carter signed the Airline Deregulation Act. Under this law, the Civil Aeronautics Board's regulation of the airlines will be phased out; the CAB itself will be dissolved in January 1985. Until then, the Act empowers the CAB to set standards to measure the "fitness" of specific airlines to operate; the Board has the authority to veto mergers of airlines. The Board's decisions will thus have a lasting effect on the competitive framework of the airline industry.

In these decisions, an important issue is whether an airline that is in financial trouble is likely to cut back on safety or services, either to weather its difficulties or to make as much money as possible before going under. Mergers affect the size and number of major airlines and, therefore, competition and finances. If the financial consequences of potential mergers were likely, in turn, to affect safety and services, the Board would be inclined to attach even greater weight to the effects of prospective mergers. The standards of "fitness" might then be set so high that only the financially soundest airlines could operate.

To shed some light on the issue, the CAB asked CNA's Public Research Institute to study the relationship between finances of major airlines and their decisions relating to safety, maintenance, and services.

To see whether a financially troubled airline does have economic incentives to cut back on safety or services, the analysts first looked at a theoretical model of airline behavior. They found that, though cutbacks may pay in some cases, the factors involved are so numerous and so complex that it is impossible to predict specific cutbacks in specific cases.

Next, they looked into the past behavior of the airlines, to find out whether they had reacted to financial problems by cutting back. The analysts studied the records of the eleven U.S. trunk airlines covering accidents, maintenance expenditures, and passenger complaints from 1965 through 1977. Maintenance expenditures for four different types of aircraft were analyzed separately. Statistics about complaints had to do with flight delays and cancellations, flight overbookings, baggage loss and damage, and baggage delays. The data, though limited in time and type of aircraft, reflected several kinds of financial experience.

In the 1960s, the trunk airlines enjoyed high earnings and rapid growth in traffic. But, in the early 1970s, after two recessions and the oil crisis of 1973-74, average airline profits went down. Over the entire period, earnings of Eastern, Pan Am, and TWA averaged no more than 5 percent of stockholder equity. Pan Am, in fact, lost money for 8 years in a row and is said to have considered bankruptcy at one point. At Braniff, Delta, National, Northwest, and Western, by contrast, earnings averaged more than 12 percent.

Despite the wide variations in earnings, both among airlines and over time, the analysts found that accidents, maintenance expenditures, and complaints were unrelated to several standard measures of the airlines' financial well-being. They concluded that none of these airlines had cut back, even though a few of them had been going through tough times. Of course, it is possible that small airlines might act differently, and there are always risks in projecting from the past to predict the future. Important uncertainties, therefore, do persist. Much can and will be learned as the industry continues to grow.

In summary, PRI's analysis suggests that the airline industry will continue to provide high levels of safety and will continue to maintain the quality of basic services, even if deregulation causes some airlines to suffer financial setbacks. The analysis also suggests, more specifically, that financial considerations need not weigh heavily in governmental decisions regarding mergers and the fitness of major airlines to operate.

Exploratory Research Division (ERD)

During 1979 the ERD completed work on underwater sound – its description via the sonar equation, the methods by which analysts model the acoustic detection process, and how the analyst determines detection performance from exercise data. In addition, an in-house course on search theory and a series of guest lectures were sponsored. Search theory addresses the questions of how to model a search and how to devise tactics that optimize its effectiveness. Guest lecturers were invited from the academic, military, and intelligence communities. The range of topics included: applications of game theory, Soviet antisatellite systems, and operations research in the USSR.

Naval Abstracts

Since 1978, CNA has published quarterly *Naval Abstracts* covering more than 4,000 articles on naval subjects and on broad strategic subjects involving the Navy. The articles come from several hundred journals printed in English, French, German, Italian, and Spanish. Each issue provides subject and author indexes, and the fourth issue of each year includes a cumulative subject index for that year.

This unique publication provides the Navy, as well as others in the defense, research, and academic communities, with reports on subjects of naval interest in the open literature. Subscriptions are available to other organizations, as well as individuals.

RESEARCH AT THE UNIVERSITY OF ROCHESTER

Under the CNA contract, 5 percent of the budget is allocated to unclassified research at the University on subjects of long-term interest and potential value to the Navy. The subjects range over various disciplines, including the physical and engineering sciences, applied mathematics, medicine, and economics and other social sciences. This was the program supported during the 1978-79 academic year.

Engineering

- Gas Absorption in Biochemical Systems
- Color Center Lasers
- Adaptive Signal Processing: Convergence Rate Analysis
- Double Resonance Experiments on Small Molecules
- Residual Stress Approach to Fatigue Crack Initiation
- Chemical Reactions at Surfaces
- Josephson Effect Weak Links
- Excitation of Long-Lived Rydbert States

Arts and Science

- Properties of a Three-Parameter Survivorship Family
- Visual Information Processing
- Mechanisms of Very Heavy Ion Reactions
- Organometallic Reaction Mechanisms
- Brain Electrical Activity and Speech Production
- Cellular Control of the Neuronal Cytoskeleton
- A 1-5μ Astronomical Spectrometer, Mees Observatory

Graduate School of Management

- Mathematical Models for Transportation Scheduling Problems
- Consumer Responses to Price Discount

Education

- Semantic, Visual Factors Interacting in Meaning Access

Medical Center

Manipulative Motivation in the Squirrel Monkey
Image Scanning and Universal Computer Coupler

School of Nursing

Body Build and Bed Surfaces, and the Formation of Decubitus Ulcers

III. THE 1980 PROGRAM

During the planning of CNA's study program, suggestions for research are drawn from a variety of sources, carefully examined, and thoroughly discussed with Navy and Marine Corps officials, as well as others in the defense community. Individual projects are discussed with potential users of the research, priorities are reviewed, and duplication is eliminated. The list of projects is accordingly narrowed down.

Most of the final Navy program is agreed on by the President of CNA and the Director of Navy Program Planning, a vice admiral who is also the Scientific Officer for CNA. Similarly, the Marine Corps program is agreed on by the CNA President and the Deputy Chief of Staff for Research, Development, and Studies of the Marine Corps. An additional portion is conducted on the initiative of CNA, under a contractual provision that allows as much as 23 percent of the annual budget to be allotted to research on Navy problems that CNA regards as important.

The most important standard applied in the entire process is that the work involve issues of central importance, need an independent view, and require CNA's special expertise.

The following list of the subjects of the research planned for 1980 consists of both new and continuing work for the Navy, Marine Corps, and non-defense sponsors.

Sea Control
New: Alternative sea-based air forces, maritime patrol aircraft, helicopter tactics, fixed-wing aircraft in battle group defense
Continuing: Future tactics and systems, submarine operations in forward areas, surface ship towed arrays, fleet introduction of the SLQ-32

Strike Warfare
New: Tomahawk antiship missile
Continuing: Attack effectiveness, all-weather strike, strike escort readiness

Amphibious
New: Future amphibious assault vehicle, amphibious warfare model, experimental assault vehicle weapon station, Marine Corps mobility enhancement concept
Continuing: Advance force operations

Ground Warfare
New: Infantry weapons
Continuing: Mobile protected weapon system

Tactical Air Warfare
New: Communication and control, E-2C/F-14 surveillance capability, E-2C/EA-6B passive surveillance, EA-6B in fleet air defense, air-to-air weapons employment
Continuing: Marine Corps helicopters, automatic detection and tracking systems

Support and Logistics
New: Value of ships' overhauls, base operating support, carrier-based air logistics, shipboard parts allowance policy, ordnance rework
Continuing: Microminiature circuit repair strategies for the Marine Corps, procurement standards, updating of ship design model

C^3 and Intelligence
New: Counter-surveillance (1990), effect of Global Positioning System on mission performance, configuration of new tactical air operations central
Continuing: Tactical Combat Operations System

Manpower, Personnel, and Training
New: Enlisted assignment and selection, recruiter report card
Continuing: Personnel management in the all-volunteer force, manpower requirements analysis, validation and normalization of Armed Services Vocational Aptitude Battery, health care personnel, enlisted compensation and retention

Resources, Situations, and Capabilities
New: Strategic scenarios of Soviet naval exercises
Continuing: Sea War 85, force planning for non-NATO contingencies, rules of engagement, Plans and Policies Program: crisis management, blockades, Soviet military press, Soviet access to bases

Non-Defense Research
New: Effects of regulation on productivity growth; screening of claimants for unemployment insurance payments and the effects on their search for work; adjustment of labor to technical change, a multi-industry study; demand for civilian labor in the Federal government

Continuing: Relation between changes in trade and changes in unemployment; regional, sectoral, and community effects of increases in imports; development of fund adequacy measures for the unemployment insurance system

IV. ORGANIZATION

Four operating groups conduct CNA's research. The Office of the President provides general supervision and support, including the contribution of the Computing Services group and the participation of the Naval officers assigned to the Operations Study Group.

OFFICE OF THE PRESIDENT

The *President* of CNA is responsible to the Board of Overseers and the University of Rochester for all of CNA's activities. He selects the management, organizes the Center's activities (see figure on page 48), sees to the quality and pertinence of CNA's work, makes certain that CNA meets its contractual and security obligations, and sets CNA's policies and budgets. The President also attends to external relations: with the Department of the Navy, with the broader community of national security analysts, and with the analytical profession.

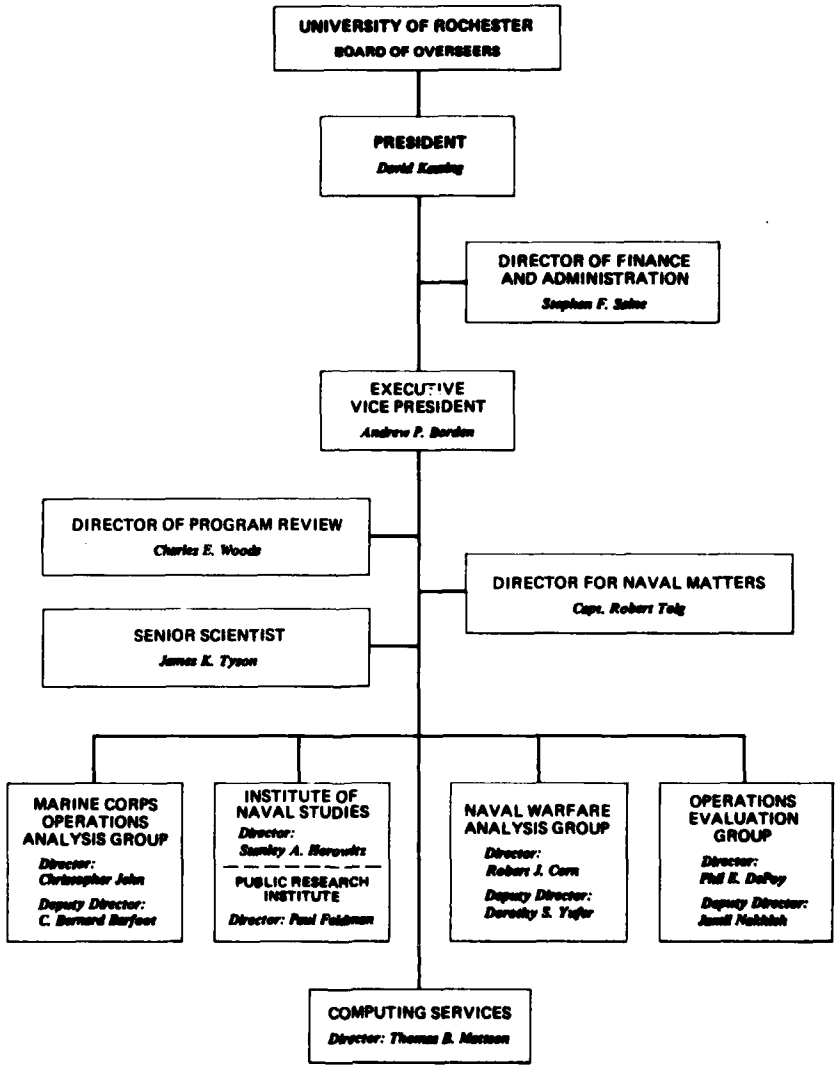
The *Executive Vice President* is primarily responsible for the timely planning, execution, review, and publication of CNA's research. To monitor the progress of studies, he oversees the milestone reporting system. He is also responsible for recruiting and assigning all members of the CNA professional staff, reviewing their performance, and setting their salaries.

The *Director of Program Review* is in charge of quality control. He checks CNA's analytical approach to each study, monitors its progress, and reviews the finished product. He sees to it that CNA's work meets the University's standards of analytical quality and that the results are so presented as to be clear and useful to decisionmakers.

The *Director of Finance and Administration* is responsible for all matters relating to financial and contractual management, for programs affecting physical security, for production and distribution of research reports, and for the operation of the Personnel Department. He is responsible for assuring compliance of CNA's security practices with the Industrial Security Regulations of the Defense Logistics Agency.

The *Senior Scientist* conducts special analyses and projects requiring unusual analytical talent and experience, and supports both the planning and reviewing activities.

THE ORGANIZATION OF CNA
(as of February 1980)



The *Director for Naval Matters,* the senior Navy Representative at CNA, has administrative responsibility for the Operations Study Group (see below). He is an ex officio member of the management staff, participates in the planning and review of studies, and maintains liaison with the Bureau of Naval Personnel to keep the OSG staffed with qualified officers. He also conducts special analyses within the CNA program.

The *Director of Computing Services* is responsible for the efficient operation and utilization of the computer center, for specific centralized programming activities, and for the continued matching of the capabilities of the computer center to the needs of the CNA research program.

The *Exploratory Research Division* is a special group within the Office of the President. Its principal responsibilities are: consolidation of professional knowledge through preparation of review material concerned with naval analysis, dissemination of professional knowledge within CNA through a program of courses and guest lectures, and advancement of professional knowledge through a program of applied research in the methodology of naval analysis.

OPERATING GROUPS

CNA's research is conducted by the Operations Evaluation Group, Naval Warfare Analysis Group, Marine Corps Operations Analysis Group, and Institute of Naval Studies. Each has its own fields of specialization.

Operations Evaluation Group (OEG)

OEG has the longest history of any of CNA's operating groups, dating back to 1942, when – as noted in section I – it was known as the Anti-Submarine Warfare Operations Research Group (ASWORG). At the time, the group was concerned with the devastating effectiveness of U-boat attacks on U.S. shipping. The group's early successes soon brought about a broadening of the areas of naval warfare in which it could demonstrate the value of its services. The U.S. Navy's enthusiasm for operations research also increased dramatically at all command levels.

A main result was the permanent establishment of OEG, with the warm support of Admiral of the Fleet Ernest L. King. As noted in the first section of this report, the field program, born of World War II, remains an important part of OEG's activities.

The program is valuable to both the comands and CNA-Washington. OEG's field representatives return after 1- or 2-year tours with the fleet and are replaced by others from the Washington office. There is therefore a continuing infusion of practical experience into OEG's studies. This is matched by a counter-infusion of up-to-date knowledge into OEG's field program. CNA and the Navy have long felt that this program results in far more practical and realistic analyses than would be possible if the analysts never left their desks. OEG has a professional staff of 60.

The major emphasis in OEG remains what it was in the earliest days of the organization – getting the most effectiveness out of the forces at hand and sending scientists to sea to help in that process. OEG is concerned with how best to use the Navy we have today and are committed to for the next few years.

As the Navy has changed, so has OEG, especially in the kinds of projects the group must undertake. Nonetheless, OEG's mode of operation has not changed significantly since its inception. OEG pioneered military operations research, both in the critical area of methodology and in the all-important relationship between civilian scientists and officers, a relationship that continues to this day. Over its lifetime, OEG has trained many hundreds of operations analysts. Its "alumni" are scattered throughout the government, the academic world, and industry; both directly and indirectly, the organization's efforts continue to benefit the nation.

Naval Warfare Analysis Group (NAVWAG)

NAVWAG was born in 1956 as a part of OEG. Its purpose was to complement OEG's expertise in operations analysis with a systems analysis capability. In 1962, NAVWAG began to grow rapidly; it became a separate operating group in 1963.

Today, NAVWAG has a professional staff of 40 analysts. Their work covers all areas of naval combat and all types of warfare systems,

including ships, submarines, aircraft, missiles, and guns, as well as detection, surveillance, and communication systems. The goal is to help the Navy decide on the size and composition of its forces and to allocate its resources most effectively.

NAVWAG looks at all aspects of naval operations, specializing in air warfare, surface warfare, amphibious warfare, antisubmarine warfare (defense of our Naval and merchant ships from enemy submarines), and undersea warfare (use of our own submarines). In recent years, NAVWAG has been analyzing the effectiveness of U.S. Naval power in worldwide conflict.

One of the main subjects of NAVWAG's research in the past few years has been the future of sea-based aviation. The Navy may develop new types of aircraft that can fly from smaller ships. The costs are great, however, and there are many uncertainties. NAVWAG has drawn on its experience in analyzing sea-based airpower to support the Navy's efforts to design its future forces.

Some of NAVWAG's analyses emphasize the physical sciences and engineering. Others extrapolate from past experience to assess the effectiveness of future systems. Yet other analyses are concerned with the economics of defense in the context of developing, producing, and operating naval systems.

Marine Corps Operations Analysis Group (MCOAG)

MCOAG was established as a section of OEG in 1962. By 1964, its value to the Marine Corps had led to a larger staff and the need to operate as a separate group.

MCOAG's professional staff of 20 analyzes a wide range of issues for Marine Corps Headquarters in Washington and for field commands around the world. These analysts examine such warfare issues as amphibious assault, ground combat, tactical air warfare, and antiair warfare, as well as non-warfare issues, including manpower and logistics.

In amphibious warfare, MCOAG has developed a series of computer models for designing alternative forces and evaluating them. One model creates equal-cost mixes of amphibious ships, landing craft, assault

vehicles, and helicopters. These forces are then evaluated with a large-scale computer model that MCOAG developed to simulate the major combat activities of an amphibious assault.

The Marines, recognizing the value of MCOAG's models for evaluating assault vehicles and analyzing landing concepts, asked that they also be applied to mixes of tactical aircraft, new infantry organizations, and contingency plans. The Navy asked that these models be used to analyze equal-cost mixes of landing craft and amphibious ships.

MCOAG has also been active in the analysis of manpower problems. Its analysts have done extensive work on manpower supply, mental aptitude testing, recruiting, retention, assignment, requirements, and quality. Because of MCOAG's expertise in these areas, the group is often called upon to work on problems of critical concern to policy-makers who must reach decisions quickly.

From this involvement, the analysts gain an understanding of current problems that frequently enriches the group's long-term study program. MCOAG analysts have been at the forefront of major changes in concepts in mental testing, manpower supply, and recruiting – all of which continue to have significant effects on the Marine Corps, as well as the larger defense community.

More than half of MCOAG's analysts have served as field representatives to Marine Corps and Navy commands. Their work is described in section I of this annual report.

Institute of Naval Studies (INS)

INS was established in 1960 to conduct studies in support of long-range planning in the Office of the Chief of Naval Operations. The first two years were devoted to studies of such technical and warfare subjects as: propulsion, command and control, satellites, data processing, antisubmarine warfare, and ocean surveillance.

In 1962, INS was combined with OEG to form CNA. INS now turned its attention to other subjects – politico-military affairs, strategic planning, and manpower. In 1966, it added two new subjects of study: the Soviet navy and logistics in U.S. Naval aviation.

INS continues to investigate problems of personnel and logistics and to conduct strategic studies and analyses of Soviet military doctrine. A Manpower Studies Division analyzes policies directed toward recruiting, training, and retaining enough qualified personnel in the all-volunteer armed forces. It also develops tools for better management of personnel. A Readiness and Logistics Division analyzes policies and expenditures in supply, transport, and maintenance. This division seeks to raise the efficiency with which funds for material support are used. A Plans and Policies Program of research examines political and military affairs in the world, with an eye to anticipating the tasks the U.S. Navy will be called upon to perform. Its findings are used in national intelligence estimates, net assessments of the naval balance, and the long-range plans of the Office of the Chief of Naval Operations.

The INS professional staff of 25 includes political scientists and historians, mathematicians and statisticians, physicists, and economists.

Public Research Institute (PRI)

PRI, administratively part of INS, has a professional staff of 7. In 1970, the Secretary of Defense suggested that the talents and techniques that had been applied successfully to defense analysis by such organizations as CNA should be applied to non-defense problems in the public sector. CNA responded by establishing PRI, which has worked on such subjects as drug abuse, the economic effects of pollution controls, health care, the effects of steel import tariffs and quotas, and unemployment insurance. PRI is a fairly small component of CNA (less than 5 percent in terms of funding), and thus does not interfere with CNA's primary mission of defense analysis.

COMPUTING SERVICES

The Computing Services group provides computing, consulting, and programming support for the CNA research program and for CNA's administrative departments. A staff of programmer/analysts develops and maintains both computer systems and applications software; an operations staff is responsible for efficient operation and use of the hardware. All provide the rest of CNA with training and consulting services. Computing Services sees to it that CNA's computing resources continue to meet the requirements of the research program.

The Computing Services staff provides analysis and programming for design, development, installation, and maintenance of software systems in three broad areas:

- Systems programming – the master control program, programming-language systems, utility programs, communications systems, and performance-measurement tools
- Applications programming – naval warfare models, interactive graphics and plotting software, simulation software, data base management systems software and applications, statistical software, and Research Analysis Language (RAL)
- Operations – file archiving, storage media transfer, and operational software.

The Computing Services staff provides CNA researchers with a full range of services. With fast response time for the time-sharing user and quick turnaround time for the batch-processing user, the computing system serves CNA analysts as a powerful and reliable research tool.

OPERATIONS STUDY GROUP (OSG)

OSG/CNA comprises about 25 Naval officers assigned to CNA as working analysts. They are selected on the basis of military experience and performance, as well as academic background. (Approximately 90 percent have postgraduate degrees.) For administrative purposes, they report to the Director for Naval Matters, a senior captain assigned to CNA, but are otherwise completely integrated with CNA's operating groups, working side by side with civilian professionals. So long as they are part of OSG/CNA, their work is directed by the President of CNA, not by the Navy.

In addition to contributing valuable analytical work themselves, they also provide CNA research with practical experience, technical knowledge, and a constructive "user's" point of view. This arrangement has worked well. These officers contribute importantly to CNA's research and add a dash of cold salt water if theoretical analyses stray too far from the realities of naval warfare. Furthermore, the OSG program provides practical training in applied analysis for these officers, who – together with the Navy itself – will benefit from the experience when they are assigned to higher positions in the future.

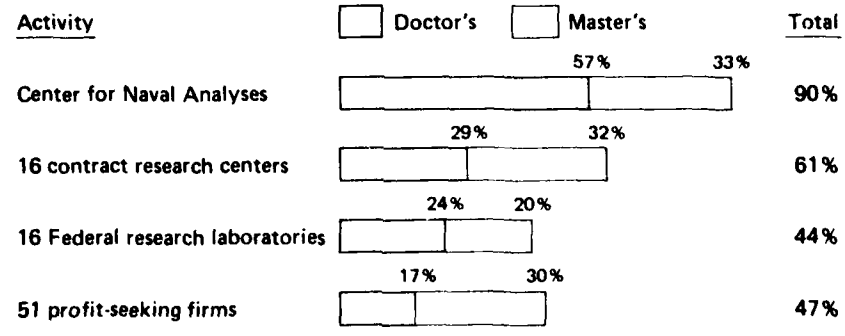
V. PERSONNEL

Management by the University of Rochester gives CNA an important advantage in attracting and retaining a staff of the quality required for work of such importance. As one result of retention, CNA has an institutional memory on which the Navy Department has often drawn.

STAFF COMPOSITION

The levels of degrees held by the professional staffs in several classes of research organizations in 1979 are compiled by the Battelle Memorial Institute. This is how the information compares with CNA data for the same period:

POSTGRADUATE DEGREES
(Proportion of professional staff, 1979)*



Source: "National Survey of Compensation Paid Scientists and Engineers Engaged in Research and Development Activities," Battelle Memorial Institute, Columbus, Ohio, November 1979.

Not only are the academic credentials of CNA's professional staff well above average, but the quality of postgraduate education is also high: Almost two-thirds of the institutions represented are top-rated in the applicable specialties, according to a survey published by the American Council on Education. Some staff members are continuing their graduate education under CNA's program for tuition reimbursement and professional development.

This was the background of the CNA professional staff as of 30 September 1979:

Average amount of postgraduate education	4 years, 1 month
Average career experience:	
Total	10 years, 4 months
Directly related to CNA research	8 years, 6 months
Proportion with field experience	50 percent
Average cumulative time in the field*	3 years, 3 months

*Of analysts with field experience.

These are the disciplines represented in the professional staff as of 30 September 1979:

	Number	Fraction of professional staff
Physics and chemistry	51	30%
Mathematics and statistics	38	22%
Economics	23	14%
Engineering	20	12%
Operations research	12	7%
Political science and international relations	5	3%
History	3	2%
Psychology and sociology	2	1%
Other	15	9%
TOTAL	169	100%

SALARIES

The Executive Vice President of CNA approves all offers of employment and all actions affecting professional staff salaries. Any salary above the maximum paid under the Civil Service General Schedule ($50,100 on 10 October 1979) must also be approved by the Executive Committee of the CNA Board of Overseers and by the Navy's

Contracting Officer. In addition, recent legislation requires the Secretary of Defense to notify Congress annually about every FCRC officer whose compensation out of Federal funds exceeds the pay authorized for level II of the Executive Schedule.

CNA's management uses salary survey data* to make sure that CNA salaries are competitive but not excessive. The surveys cover salaries paid by organizations in fields generally similar to CNA's. The surveys also include salary data for a large national sample of scientists and engineers by degree, specialty, and level of experience. This information is supplemented with informal exchanges with other organizations. Salaries and performance are reviewed every year in an assessment of individual contributions to the research program.

Affirmative Action and Equal Employment Opportunity

CNA has long supported the principle of equal opportunity, regardless of race, creed, color, national origin, sex, or physical handicap. To that end, CNA has established policies and practices in conformity with Federal legislation and has an Affirmative Action Program. CNA's first written Affirmative Action Program was submitted to the Department of Health, Education, and Welfare in April 1970. A revised program was submitted in 1972. The main purposes of the program are: 1) to make sure that within each sector of the labor market drawn on by CNA, minorities are represented on the CNA staff to the same degree as they are in the sector as a whole, and 2) to provide all employees with opportunities for training and advancement. CNA is dedicated to these objectives.

*The Battelle survey, "Annual CNA Subset Survey of Professional Staff Salaries in Selected FCRCs," and "Annual Executive Salary Survey" by the Rand Corporation.

VI. FINANCIAL INFORMATION

Our system of financial controls follows standard financial practice and, in addition, meets the requirements of Federal regulations. These are the main features of CNA's financial system:

Budgets CNA is decentralized in operation. Group directors and department managers have their own annual budgets and are responsible for performing assigned tasks within them. Expenditures are compared with budgets once a month.

Cash Requirements CNA's contract with the Navy provides access to working capital through an advance funding account. Advances are drawn weekly, on the basis of anticipated expenditures, and offset by vouchers.

Reporting System Costs are reported on a fiscal year basis, with interim monthly reports. Government auditors have reviewed the CNA accounting system and approved it.

Expenditure Review All contract expenditures are reviewed by the Director of Finance and Administration and his staff. In FY 1979, about 72 percent of all expenditures (see page 62) went for staff salaries and related benefits. Expenditures for travel, supplies, equipment, and consultants are documented by requisitions and approved by CNA's management. Every major procurement must be reviewed and approved by the Administrative Contracting Officer before the purchase is made.

Audit Review The CNA financial system is audited by CNA's internal auditors, the Defense Contract Audit Agency, and the University's public accountants (Peat, Marwick and Mitchell).

The following tables outline the financial status of CNA.

FUNDING IN FY 1979

(Thousands of dollars)

Source of funds	
Defense:	
CNO/CMC study program	$10,188
Tactical Analysis Group	1,893
Marine Corps studies and analyses	446
Other programs	505
Total defense	13,032
Non-defense:	
Department of Labor	297
National Science Foundation	183
U.S. Coast Guard	152
Civil Aeronautics Board	59
Total non-defense	691
Total FY 1979 funds available	13,723
Funds carried forward to FY 1980	(377)
Total funds expended	$13,346
Application of funds	
CNA program costs	$12,665
On-campus research	681
Total funds applied	$13,346

STATEMENT OF COMPARATIVE FINANCIAL CONDITION
30 September 1979 and 30 September 1978

ASSETS

	1979	1978
Current assets		
Cash	$ 269,565	$169,968
Receivables (note 1)	194,755	127,700
Travel advances and prepaid items	230,462	255,823
Advances – U.S. Navy	325,838	438,598
Total current assets (note 2)	$1,020,620	$992,089

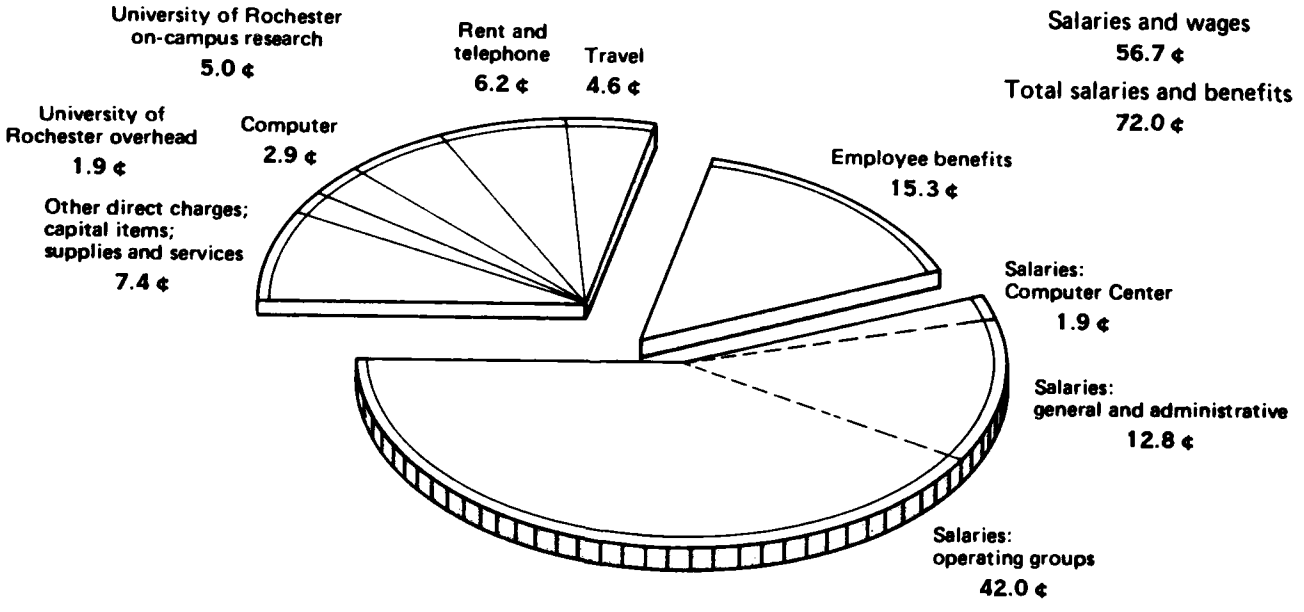
LIABILITIES AND RESERVE FOR DISALLOWANCES

Current liabilities		
Accounts payable	$ 194,660	$215,884
Payroll taxes and other withholdings	5,136	6,195
Total current liabilities	199,796	222,079
Other liabilities		
Accrued annual leave	779,110	730,940
Unbilled labor adjustments	41,714	37,561
Total other liabilities	820,824	768,501
Total liabilities	1,020,620	990,580
Reserve for disallowances (note 3)	-	1,509
Total liabilities and reserve for disallowances	$1,020,620	$992,089

NOTES:

1. Government agencies account for over 95 percent of all receivables.
2. CNA has no physical assets. Property and equipment constitute direct charges, with title vesting in the government.
3. Reserves are the excess of funding over costs incurred on non-defense contracts.

APPLICATION OF THE RESEARCH DOLLAR IN FY 1979



VII. BOARD OF OVERSEERS

According to the Bylaws of the Board of Overseers:

> The Board . . . shall have the responsibility for formulating overall policy for the Center . . . It shall be responsible for maintaining high standards of professional competence and integrity in CNA's work and it shall review the general management policies and personnel of the Center.

At its three regular meetings each year, the Board reviews the work of CNA. At one meeting, held at the Center's offices, the methods and results of major research are presented in detail to the Board. Typically, about six projects, covering classified work done in the Washington area, are reviewed.

A second meeting is held near a CNA field office. This gives the Board an opportunity to review operational analyses done for the operating forces of the Navy and Marine Corps.

Unclassified research for Navy, Marine Corps, and non-defense sponsors is usually presented to the Board at a meeting held at the University. The Board thus has the benefit of the views of University faculty members about the competence of CNA's work.

MEMBERS

W. Allen Wallis, Chairman of the Board
Chancellor and Honorary Trustee, University of Rochester

Martin J. Bailey, Professor of Economics, University of Maryland. Former Assistant for Southeast Asia Forces, Department of Defense.

Andrew P. Borden, Executive Vice President of the Center for Naval Analyses. Former Chief Scientist, Systems Analysis Division, Office of the Chief of Naval Operations.

Kenneth E. Clark, Dean of the College of Arts and Sciences, University of Rochester. Former member of the Army Science Advisory Panel (now known as the Army Science Advisory Board) and consultant to the Office of Science and Technology.

Adm. C. Donald Griffin, USN (Ret.), former Deputy Chief of Naval Operations. Former Commander in Chief, U.S. Naval Forces, Europe. Former Commander in Chief, Allied Forces, Southern Europe.

Donald K. Hess, Vice President for Campus Affairs, University of Rochester. Former Director, U.S. Peace Corps. Former Director for Program Management, Advanced Research Projects Agency.

Arthur Kantrowitz, Professor of Engineering, Dartmouth College. Chairman and Chief Executive Officer of Avco Everett Research Laboratory (Ret.). Honorary Trustee of the University of Rochester.

David Kassing, President of the Center for Naval Analyses. Former Director of Research of the President's Commission on an All-Volunteer Armed Force. Former Director of Naval Forces Division, Office of the Assistant Secretary of Defense (Systems Analysis).

William H. Meckling, Dean of the Graduate School of Management, University of Rochester. Member of the National Science Board. Former Executive Director of the President's Commission on an All-Volunteer Armed Force. Former President of the Center for Naval Analyses.

Elliot W. Montroll, Albert Einstein Professor of Physics, University of Rochester, and Director of the Institute for Fundamental Studies. Former Vice President, Institute for Defense Analyses.

William A. Nierenberg, Director of the Scripps Institution of Oceanography.

Frank P. Sanders, Vice President of The Signal Companies, Inc. Former Under Secretary of the Navy.

Robert L. Sproull, President and Trustee of the University of Rochester. Former Chairman, Defense Science Board. Former Director, Advanced Research Projects Agency.

Brian J. Thompson, Dean of the College of Engineering and Applied Science, University of Rochester. Former Director of the Institute of Optics, University of Rochester.

LaRoy B. Thompson, Senior Vice President and Treasurer of the University of Rochester. Member (and former Chairman) of the Board of Associated Universities.

Adm. W. F. A. Wendt, USN (Ret.), former Deputy Chief of Naval Operations. Former Commander in Chief, U.S. Naval Forces, Europe.

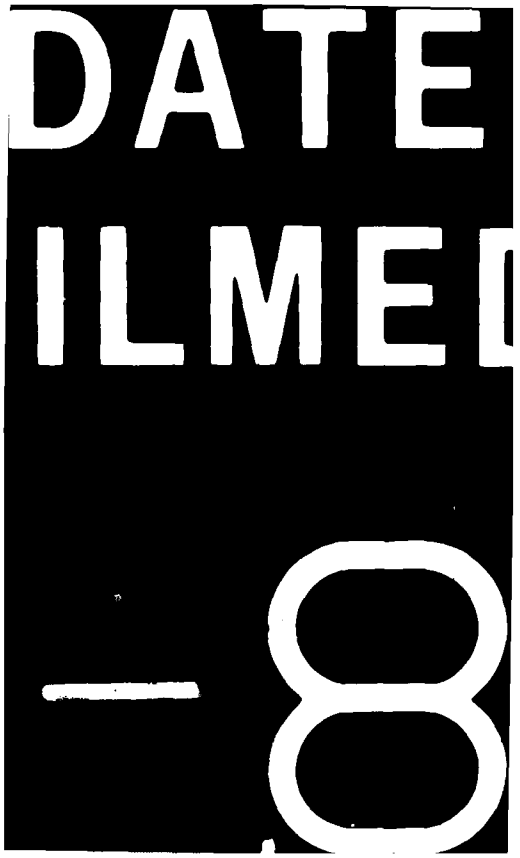
Albert Wohlstetter, Professor, University of Chicago. Former member of the professional staff and Research Council, the Rand Corporation.

Clarence L. A. Wynd, former Vice President and Director, the Eastman Kodak Company. Honorary Trustee of the University of Rochester.

PAST MEMBERS

Carl Amthor (1969-72)
Charles J. DiBona (1967-73)
McRea Hazlett (1967-71)
Hubert Heffner* (1973-75)
Robert Loewy (1967-74)
Stephen Lukasik (1975-77)
David A. McBride (1967-78)
Russell Murray 2nd (1974-77)
Patrick Parker (1967-72)

**Deceased*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